

Reexamining the Role of Land in Economic Growth

María Dolores Guilló*
guillo@merlin.fae.ua.es

Fidel Perez-Sebastian*
fidel@merlin.fae.ua.es

February 2010

Abstract

This paper reconciles the traditional view that land increases the wealth of nations with recent empirical findings that point out that natural inputs such as land are negatively related to growth. Our theory shows, within a two-sector neoclassical growth model with international trade in goods, that land directly affects both long-run income and transitional growth. These two effects can be positive or negative depending on input elasticities. Furthermore, they go in opposite directions, creating a tension that complicates the interpretation of estimated-coefficient signs in growth regressions. Quantitative results show that the two effects can be significant. We also produce empirical evidence that suggests a negative effect of land per worker on growth, but a positive impact on long-run income.

JEL Classification: O11, O13, O41, F11, F43.

*Guilló: Department of Economics and IUDESP, Perez-Sebastian: Department of Economics, Universidad de Alicante. Postal address: Departamento de Fundamentos del Análisis Económico, Universidad de Alicante, Campus de San Vicente s/n, 03690 Alicante, Spain. We thank Jaime Alonso-Carrera, Francesco Caselli, Oded Galor, Delfim Gomes Neto, Rachel Ngai, Xavier Raurich, Diego Restuccia, Pierre Sartre, David Weil, and seminar participants at the University of Barcelona, Brown University, the Richmond Fed, the University of Vigo, and the 2007 SED meeting in Prague for helpful comments. This research was partially supported by the Spanish Ministry of Science and Technology, SEJ 2007-62656, FEDER funds, and by the Instituto Valenciano de Investigaciones Económicas.

1 Introduction

Land is, indisputably, an important factor of production, not only for agriculture but also for manufacturing and services; without land, no economic activity can take place. This traditional view that land substantially contributes to a nation's wealth (e.g., see Smith, 1776, Malthus, 1798, and Schultz, 1967) contrasts to the empirical findings. Land and, in general, natural inputs show up most of the time in growth regressions as a curse to economic growth. Doppelhofer *et al.* (2004) and Sachs and Warner (2001), for example, find that land area divided by population and the share of exports of primary products in GDP, respectively, are negatively related to growth. In this paper, we offer a theory, and evidence that can reconcile these two views: land can be beneficial for long-run per capita income but harmful for growth.

More specifically, we reexamine the role of land within a globalized world. We start by introducing the natural input into a dynamic Heckscher-Ohlin model of international trade and growth. The economy is composed of a large number of small open economies. Each country has the production structure of the two-sector neoclassical growth model with agricultural and non-agricultural goods. The two sectors employ land, capital and labor, and have different input intensities. Unlike capital and labor, the potential supply of land is fixed, and its use intensity is relatively small in the non-primary sector. All nations possess identical preferences and production technologies, but they may differ regarding the land endowment. Some countries, the developed world, have already reached the steady state, while other countries begin to develop. We study the effect of land on long-run per-capita income, and on the asymptotic speed of convergence.

We obtain several interesting results from the theoretical model. First, we establish a novel role of land that affects economic growth through the convergence speed. This effect occurs in diversified small-open economies that take the relative price of goods as given by international markets. Because of this, sectoral labor reallocations generated by land-endowment variations become larger, changing the curvature of the marginal-productivity function of capital and, as a consequence, the convergence speed. More land per worker slows down convergence when agriculture has a larger capital elasticity. Otherwise, as long as sectors show different capital shares, land per worker speeds up transitional growth. If capital shares are the same, the economy is closed, or there is specialization, the speed of convergence is independent of the land endowment.

Second, larger stocks of land can have positive or negative effects on long-run income, depending, again, on input elasticities and trade patterns. More specifically, a larger

land endowment leads to higher long-run income levels if agricultural goods are less labor intensive. However, if the production of agricultural goods is relatively labor intensive, a larger stock of land has such a negative influence on capital accumulation that leads the small-open economy to permanently lower levels of income. When the economy specializes in production, steady-state output always increases with land. Interestingly, in all cases, steady-state consumption and, therefore, welfare increase with the relative stock of land.

Quantitative results say that these effects of the natural input can be significant. In the calibrated economy, cross-country differences in land per capita can explain up to a 7-fold in long-run per capita income, and more than a 2-fold in the convergence speed.

Importantly, we find that the long-run and transitional effects of land run in opposite directions. Depending on input shares, a different land endowment may bring a larger steady-state income level along with a lower speed of convergence or *vice versa*. This creates a tension that can make land show up in the data as a curse for economic growth even when it positively affects steady-state output.

After analyzing the model, we empirically test its predictions. The paper first derives empirical specifications from the theoretical framework. After that, these econometric models are estimated using first simulated data, and then a cross-section of 80 nations for the period 1967 to 1996. We obtain results using OLS and GMM for three different measures of land: arable land, potential arable land, and total area. Estimates are in line with the model predictions. The empirical results give weak support to a negative and significant effect of land per worker on the convergence speed, but point out to a positive effect on long-run income.

Few papers have focused on the role of land *per se* in the process of growth. For example, Nichols (1970) incorporates land in a Solow growth model and shows that it can harm long-run income.¹ Adamopoulos (2008) and Galor *et al.* (2008) emphasize that land-ownership inequality can delay industrialization through its effect on the import of intermediate goods used in industry and the implementation of human-capital promoting institutions, respectively.² We differ from them, among other things, in that we focus on land effects that are a consequence of *Rybczynski-type* mechanisms.

The literature on the importance of agriculture in shaping economic development and growth is also related to our work. Traditional theories of structural change emphasize

¹See Sorensen and Whitta-Jacobsen (2005, chapter 7), for example, for a review of extensions of the Solow model that include scarce resources.

²Gylfason (2001) and Mehлум *et al.* (2006) defend related ideas, but focussing on natural resources. Gylfason (2001) argues that natural riches may develop a false sense of security and harm human capital accumulation and growth. Mehлум *et al.* (2006) provides evidence that institutional quality is key to understand why natural inputs are a blessing for some nations, but a curse for other countries.

two main forces that induce movements of resources across sectors along the development path: sector-biased technical change (Ngai and Pissarides 2007), and non-homothetic preferences (Konsamut *et al.* 2001). These mechanisms are also exploited by other papers such as Galor and Weil (2000), Caselli and Coleman (2001), Kögel and Prskawetz (2001), Hansen and Prescott (2002), Irz and Roe (2005), Gollin *et al.* (2007), and Restuccia *et al.* (2008) that explicitly include land in the agricultural technology to show how agriculture affects the industrialization-process take-off, and helps explain cross-country differences in productivity and income. Our paper proposes a third mechanism that generates resource reallocations, differences in input elasticities across sectors, and shows that it can be potentially important for small open economies.

Finally, multi-sector models of international trade and growth include Ventura (1997), Mountford (1998), Atkeson and Kehoe (2000), Bajona and Kehoe (2006), Galor and Mountford (2006,2008), and Guilló and Perez-Sebastian (2007). We share with them that the main results are driven by the flow of resources across domestic sectors. Unlike us, the first three use more or less standard versions of the two-sector neoclassical framework that do not include land. Neither do Galor and Mountford (2006, 2008), which focus on the fertility and human capital dimensions. Guilló and Perez-Sebastian (2007) present a similar model, but only study the effects of fixed sector-specific inputs on steady-state income.

The rest of the paper is organized as follows. Section 2 describes the economic environment. Section 3 analyzes the impact of land on a small-open developing nation. A numerical exploration of the model predictions is carried out in section 4. Section 5 presents the empirical evidence. Section 6 concludes.

2 The Environment

Consider a world economy consisting of a large number of small open economies that differ only in their land/labor endowments and level of development. There are two goods and three inputs of production. The production of the agricultural and non-agricultural goods needs capital, labor, and land inputs, which can freely move across sectors.³ There is free

³Land employed in agriculture and non-agriculture might be thought as not necessarily having the same nature. In this sense, land could be considered as an specific factor. This would not change the basic results of the paper. This conclusion can be extracted from a previous version of our paper. More specifically, in Guillo and Perez-Sebastian (2005), we employ a setup that differs from the current one only in that the two goods are a consumption product and an investment good, and land is specific to the production of the former. This previous version obtains effects of land that are qualitatively the same and quantitatively very similar to the ones obtained now.

trade in goods, but international movements of inputs are prohibited.⁴ All markets are perfectly competitive. The land endowment is fixed but population grows at a common constant gross rate G_L in all countries.⁵

Infinitely-lived households discount future utility with the factor ρ . All household members possess identical preferences defined only over consumption of agricultural (c_{at}) and non-agricultural (c_{mt}) goods. In particular, their preferences are given by

$$\sum_{t=0}^{\infty} \rho^t L_t [\varphi \ln c_{at} + (1 - \varphi) \ln c_{mt}], \quad \rho, \varphi \in (0, 1), \quad 0 < \rho G_L < 1. \quad (1)$$

Individuals offer labor services and rent capital and land to firms. The total amount of land in the economy is fixed over time, it equals N , and it is uniformly distributed across all individuals. Since in each period international trade must be balanced, consumers in each household face the following budget constraint

$$c_{at} + p_t(c_{mt} + x_t) = r_{kt}k_t + r_{nt}n_t + w_t, \quad (2)$$

where the evolution of capital per worker is governed by

$$G_L k_{t+1} = (1 - \delta) k_t + x_t. \quad (3)$$

In the above expressions, x_t is the per capita demand of non-agricultural goods used for investment, whose price is p_t ; r_{kt} , r_{nt} , and w_t are, respectively, the rental rates on capital, land, and labor; n_t and k_t denote the amount of the natural input and capital owned by the individual at date t , respectively.⁶ The agricultural good is the numeraire.

Households in each country will maximize (1) subject to (2) and (3), taking as given the world output prices and the domestic rental rates for production factors. Consumption will be split between the two goods according to

$$\frac{c_{at}}{c_{mt}} = \left(\frac{\varphi}{1 - \varphi} \right) p_t. \quad (4)$$

⁴Not all non-agricultural goods are tradable. For example, the scale of trade in services is smaller than in manufacturing. Appendix B shows, however, that this assumption should not have a big impact on our results.

⁵Galor and Weil (1999, 2000) and Ashraf and Galor (2008) show that Malthusian population dynamics can have important effects on economic growth and development. It can then be argued that Malthusian forces could as well equalize land-labor ratios across nations. This however would be possible only over very long horizons. As Gallup *et al.* (1999) show, the distribution of population around the world varies enormously, depends mainly on geographical features, and was heavily influenced by demographic trends well before the period of modern economic growth. Even correcting for quality, land per worker differences across nations are substantial. For example, the equivalent potential land measure computed by FAO displays, in per worker terms, a coefficient of variation of 1.53 for the sample of countries that we employ later on in section 5; number that is similar to the one for potential arable land.

⁶In the model, variables in per-capita terms and in per-worker terms coincide.

In addition, the Euler equation corresponding to this dynamic programming problem is

$$\frac{c_{t+1}}{c_t} = \frac{p_{t+1}}{p_t} \rho \left(\frac{r_{kt+1}}{p_{t+1}} + 1 - \delta \right), \quad (5)$$

where $c_t = c_{at} + p_t c_{mt}$ is total aggregate consumption per capita. Equation (5) is standard. It says that the growth rate of consumption depends on the present-utility value of the rate of return to saving. This return reflects that giving up a unit of present consumption allows buying $1/p_t$ units of the investment good today that, after contributing to the production process, will covert themselves tomorrow in $(1 + r_{kt+1}/p_{t+1} - \delta)$ units that can be sold at a price p_{t+1} .⁷

In each nation, production of the agricultural good (Y_{at}) is given by

$$Y_{at} = A E_{at}^{1-\alpha} K_{at}^\alpha N_{at}^\beta L_{at}^{1-\alpha-\beta} = A E_{at}^{1-\alpha} L_{at} k_{at}^\alpha n_{at}^\beta, \quad \alpha, \beta, \alpha+\beta \in (0, 1). \quad (6)$$

And the production of non-agriculture (Y_{mt}) by

$$Y_{mt} = B E_{mt}^{1-\theta} K_{mt}^\theta N_{mt}^\gamma L_{mt}^{1-\theta-\gamma} = B E_{mt}^{1-\theta} L_{mt} E_t k_{mt}^\theta n_{mt}^\gamma, \quad \theta, \gamma, \theta+\gamma \in (0, 1). \quad (7)$$

In the above expressions K_{it} , L_{it} and N_{it} denote, respectively, the amount of capital, labor and land devoted in period t to the production of good i , and $k_{it} = K_{it}/L_{it}$ and $n_{it} = N_{it}/L_{it}$ the relative uses of capital and land, for $i = a, m$. E_{it} stands for the efficiency level of land and labor in sector i at period t that grows at a common exogenous gross rate $G_{E_i} \geq 1$ in all countries. We shall assume that sectoral efficiency levels are initially the same, $E_{a0} = E_{m0} = E$, although E can differ across countries. A and B are constant positive efficiency parameters common to all countries.

Let us denote the labor share in the production of good i by $l_{it} = L_{it}/L_t$. Notice that because consumers are alike, the amount of capital owned by each individual will equal the country's capital-labor ratio. Hence, the constraints on labor, capital, and land within a country can be written as follows:

$$l_{at} + l_{mt} = 1, \quad (8)$$

$$l_{at} k_{at} + l_{mt} k_{mt} = k_t, \quad (9)$$

$$l_{at} n_{at} + l_{mt} n_{mt} = n_t. \quad (10)$$

⁷We could introduce a minimum consumption level of agricultural goods in household's preferences, expression (1). In fact, minimum consumption can make land affect positively transitional growth at early stages of the adjustment process, as Irz and Roe (2005) show. This survival consumption requirement would not, however, affect our results. The reason is that its effect disappears asymptotically as the economy approaches the steady state. Therefore, it should have a negligible impact on steady-state outcomes and on the asymptotic speed of converge.

Firms in each country will maximize profits taking as given world prices and the domestic rental rates on production factors. From the production functions (6) and (7), production efficiency implies that

$$r_{kt} = \alpha A E_{at}^{1-\alpha} k_{at}^{\alpha-1} n_{at}^{\beta} = p_t \theta B E_{mt}^{1-\theta} k_{mt}^{\theta-1} n_{mt}^{\gamma}, \quad (11)$$

$$r_{nt} = \beta A E_{at}^{1-\alpha} k_{at}^{\alpha} n_{at}^{\beta-1} = p_t \gamma B E_{mt}^{1-\theta} k_{mt}^{\theta} n_{mt}^{\gamma-1}, \quad (12)$$

$$w_t = (1 - \alpha - \beta) A E_{at}^{1-\alpha} k_{at}^{\alpha} n_{at}^{\beta} = p_t (1 - \theta - \gamma) B E_{mt}^{1-\theta} k_{mt}^{\theta} n_{mt}^{\gamma}. \quad (13)$$

Of course, these equalities will hold only for the technologies that are used in equilibrium. The following proposition establishes the firms that open in equilibrium.⁸

Proposition 1 *Domestic firms will enter the market of manufactures if*

$$p_t > \frac{A}{B} \frac{E_{at}^{1-\alpha}}{E_{mt}^{1-\theta}} \left(\frac{\alpha}{\theta}\right)^{\theta} \left(\frac{\beta}{\gamma}\right)^{\gamma} \left(\frac{1-\alpha-\beta}{1-\theta-\gamma}\right)^{1-\theta-\gamma} n_t^{\beta-\gamma} k_t^{\alpha-\theta}. \quad (14)$$

And no firm will enter the market of agricultural goods if

$$p_t \geq \frac{A}{B} \frac{E_{at}^{1-\alpha}}{E_{mt}^{1-\theta}} \left(\frac{\alpha}{\theta}\right)^{\alpha} \left(\frac{\beta}{\gamma}\right)^{\beta} \left(\frac{1-\alpha-\beta}{1-\theta-\gamma}\right)^{1-\alpha-\beta} n_t^{\beta-\gamma} k_t^{\alpha-\theta}. \quad (15)$$

The right side of expression (14) determines a minimum price above which it becomes profitable for the producers of non-agricultural products to enter the market. This minimum price depends on the relative endowment of land, the stock of capital per capita, the sector productivities and the factor intensities, let us denote it by $p^{\min}(k_t; n_t, E_{at}, E_{mt})$. A small open economy then specializes in the production of *a*-goods if $p^{\min}(k_t; n_t, E_{at}, E_{mt})$ is greater than or equal to the international price p_t . More specifically, if the production of agricultural goods is more land intensive than the production of non-agricultural ones, closing the non-agricultural sector becomes more appealing as n_t increases and as p_t declines or, in other words, as the agricultural-goods activity becomes relatively more productive for given k_t . In addition, if this activity is more capital intensive than production in non-agriculture, larger values of k_t have the same effect as larger stocks of n_t . The right side of the second inequality, expression (15), determines a maximum price above which it is not profitable to allocate any resources into the agricultural sector, let us denote it by $p^{\max}(k_t; n_t, E_{at}, E_{mt})$. The interpretation of this second condition follows the same logic as the one of condition (14).

Furthermore, notice that $p^{\min}(k_{at}; n_{at}, E_{at}, E_{mt}) = p^{\max}(k_{mt}; n_{mt}, E_{at}, E_{mt})$ under diversification, and that this value must equal the international price level p_t at every

⁸The proofs of the propositions presented in the paper are in appendix A.

point in time t for the market-equilibrium zero-profit condition to hold, a property that will prove helpful in our analysis.

From the firms' optimality conditions, we can derive expressions for input intensities in each sector under diversified production. Define the relative factor price $\omega_{kt} = w_t/r_{kt}$. The efficiency conditions in production (11) and (13) determine the optimal allocations of capital as a function of this relative factor price:

$$k_{mt} = \left(\frac{\theta}{1 - \theta - \gamma} \right) \omega_{kt}, \quad (16)$$

$$k_{at} = \left(\frac{\alpha}{1 - \alpha - \beta} \right) \omega_{kt}, \quad (17)$$

It follows from (16) and (17) that agricultural goods will be more capital-labor intensive if and only if $\theta(1 - \beta) < \alpha(1 - \gamma)$. Similarly, defining the relative factor price $\omega_{nt} = w_t/r_{nt}$, (12) and (13) yield that

$$n_{mt} = \left(\frac{\gamma}{1 - \theta - \gamma} \right) \omega_{nt}, \quad (18)$$

$$n_{at} = \left(\frac{\beta}{1 - \alpha - \beta} \right) \omega_{nt}. \quad (19)$$

These two expressions imply that the production of agricultural goods will be more land-labor intensive than the production in non-agriculture if and only if $\beta(1 - \theta) > \gamma(1 - \alpha)$.

From equations (8), (9), (16) and (17), we can write

$$k_t = k_{mt} \left[(1 - l_{mt}) \frac{(1 - \theta - \gamma)\alpha}{\theta(1 - \alpha - \beta)} + l_{mt} \right]. \quad (20)$$

And from expressions (8), (10), (18) and (19),

$$n_t = n_{mt} \left[(1 - l_{mt}) \frac{(1 - \theta - \gamma)\beta}{\gamma(1 - \alpha - \beta)} + l_{mt} \right]. \quad (21)$$

It is also possible relating n_{mt} and k_{mt} . In particular, equation (11) implies that

$$n_{mt} = \left[\frac{r_{kt}}{\theta p_t} \left(\frac{k_{mt}}{E_{mt}} \right)^{1-\theta} \right]^{1/\gamma}. \quad (22)$$

Another interesting variable is aggregate per capita output, defined as a weighted sum of agricultural- and non-agricultural-goods production,

$$y_t = l_{at}y_{at} + p_t l_{mt}y_{mt}. \quad (23)$$

Using expressions (6) to (8), (13) and (23) we can write a nation's GDP level per capita under diversified production as

$$y_t = \frac{w_t}{1 - \alpha - \beta} \left[1 + l_{mt} \left(\frac{\theta + \gamma - \alpha - \beta}{1 - \theta - \gamma} \right) \right]. \quad (24)$$

It is interesting to note that the economy's GDP can decrease with a larger allocation of labor into the production of agricultural goods if this activity is more labor intensive than non-agriculture.

Before finishing this section, let us briefly describe the steady-state equilibrium path. Over there, the employment of land in each sector, the labor shares and the rental price of capital will remain invariant, and the rest of variables will grow at constant rates. Denote by an asterisk (*) steady-state outcomes, then the consumers' optimality condition (5) implies

$$\frac{r_{kt}^*}{p_t^*} = G_k^* \rho^{-1} + \delta - 1; \quad (25)$$

where G_i represents the gross rate of growth of variable i . Here we have used the result that $G_c^*/G_p^* = G_k^*$.⁹

3 The Developing Small-Open Economy

Suppose that all but one of the countries that compose our economy are identical in all aspects and have already reached the steady-state. We can think of this group of nations as the developed world.¹⁰ The equilibrium value of the relative price of goods, p_t^* , will be pinned down by this developed world, and will not be affected by the behavior of the small (still developing) country.¹¹ We shall assume throughout that the land share in agriculture is larger than the land share in non-agriculture, that is, $\beta > \gamma$.

Consider the small nation with an initial capital stock such that it is still moving along its adjustment path. It faces the steady-state relative output price $p_t = p_t^*$ for all t . Substituting this price in equations (2) to (13), we obtain the equation system that characterizes the late-blooming nation's dynamics. It can be easily shown that the developing economy will accumulate capital until its rental rate falls down to the world's rate r_{kt}^* , which is by equation (25) exclusively determined by consumers' preferences and p_t^* , and that its pattern of production along the adjustment will follow from Proposition 1. However, evaluating the impact of land on growth along this transitional process requires the use of numerical methods; the next section carries out this numerical exercise. Here, we focus on the steady-state scenario, which can be studied analytically.¹²

⁹Steady state growth rates for the different variables are given in appendix A.

¹⁰A full description of the behavior of the developed world is provided in appendix A.

¹¹The international relative price of final goods is derived in the appendix, and given in equation (43).

¹²Atkeson and Kehoe (2000) show that, in the standard dynamic Heckscher-Ohlin model, a country that starts developing later than the world economy remains permanently poorer. Guillo and Perez-Sebastian (2008), however, prove that this is not the case when inputs in fixed supply such as land are present.

From now on, the asterisk (*) denotes the international diversified-production equilibrium for the world economy, which is not affected by a small-open economy's behavior, whereas the superscript (ss) denotes the steady state values for the less developed country. Expressions (14) and (15) determine the threshold levels for the capital stock that define the small economy's diversification interval for given p_t^* , n_t and the sector efficiency levels. Consider, first, the case of a late-bloomer that ends its development path diversifying production. Given that $r_{kt}^{ss} = r_{kt}^*$, equations (11) to (13), (22) and (25) imply that the long-run (sector-efficiency-adjusted) capital-labor ratio in non-agriculture will equal the one of the world economy, $k_{mt}^{ss}/E_{mt} = k_{mt}^*/E_{mt}^*$. This is all you need to guarantee in the long run that the same will be true in agriculture, $k_{at}^{ss}/E_{at} = k_{at}^*/E_{at}^*$, that (sector-efficiency-adjusted) factor-price equalization holds, $w_t^{ss}/E_{it} = w_t^*/E_{it}^*$ and $r_{nt}^{ss}/E_{it} = r_{nt}^*/E_{it}^*$ for $i = a, m$, and that the country will be using the same land-labor ratios as the rest of the world, $n_{at}^{ss} = n_{at}^*$ and $n_{mt}^{ss} = n_{mt}^*$.

The difference with the world economy will come regarding the labor allocations and the overall capital stock of the developing nation. The labor share in agriculture l_a^{ss} will always rise with the land endowment since we assume that this sector is more land intensive. The stock of capital per worker k_t^{ss} , in turn, will increase with n_t if agriculture is more capital intensive; it will fall with n_t otherwise. To see this, notice that at the steady state $k_t^{ss} = l_a^{ss} k_{at}^* E_{at}/E_{at}^* + (1 - l_a^{ss}) k_{mt}^* E_{mt}/E_{mt}^*$, and that $k_{at}^* E_{at}/E_{at}^*$ and $k_{mt}^* E_{mt}/E_{mt}^*$ are exogenous constants to the small open economy and do not depend on its land endowment.

As a result, the effect of an increase in land on long-run income can be also positive or negative. From the economy's demand-side point of view, income per worker can be written as $y_t^{ss} = w_t^* E/E^* + r_{kt}^* k_t^{ss} + r_{nt}^* E/E^* n_t$. In this expression, land rents always rise with n_t .¹³ However, arguments above imply that the steady-state capital and, then, interest payments can go up or down. As equality (24) says, the consequence is that whether or not y_t^{ss} rises depends ultimately on inputs' elasticities. More specifically, a larger land-labor endowment of the small developing economy will have a positive effect on long-run per capita income if the production of agricultural goods is less labor intensive than in non-agriculture, otherwise larger values of n_t will be associated to smaller values of y_t^{ss} .

From the economy's production side, the forces that lead to this finding are the follow-

¹³Balanced trade implies that savings are equal to gross investment at every period, so the relationship between savings and the land endowment at the steady state is the same as the one between the capital stock and n .

ing. On the one hand, more land increases the productivity of all inputs; this is good for income. On the other, the increase in the fixed factor reallocates capital and labor from the rest of the economy to the sector that is more land-labor intensive, agriculture. In a small-open economy for which the world's relative price is given, the latter *Rybczynski effect* implied by the augmented factor can reverse the positive productivity effect, and generate a lower long-run per capita income when agriculture is less capital intensive.

Consider now the scenario of long-run specialization, which has also interesting implications. Proposition 1 implies that specialization in agricultural goods will occur in the long run whenever $n_t \geq n_{at}^*$. In that case, income per capita is given by $y_t^{ss} = AE_{at}^{1-\alpha} (k_t^{ss})^\alpha n_t^\beta$, with $k_t^{ss} = k_{at}^* (n_t/n_{at}^*)^{\beta/(1-\alpha)} E/E^*$, which follows from the equalization of interest rates, $r_{kt}^{ss} = r_{kt}^*$. This proposition also says that long run specialization in non-agriculture will happen whenever $n_t \leq n_{mt}^*$, which implies a steady state income equal to $y_t^{ss} = p_t^* B E_{mt}^{1-\theta} (k_t^{ss})^\theta n_t^\gamma$, with $k_t^{ss} = k_{mt}^* (n_t/n_{mt}^*)^{\gamma/(1-\theta)} E/E^*$. Therefore, in either case income increases with the land endowment. Moreover, long run income can be above the world's average if n_t is sufficiently large.

The next proposition summarizes these results.

Proposition 2 *Suppose a small open economy that starts its adjustment path with a capital-labor endowment $k_0/E < \min \{k_a^*/E^*, k_m^*/E^*\}$ and a stock of land N . (a) At the steady state, it will diversify production if $n_{mt}^* < n_t < n_{at}^*$, it will specialize in the production of a -goods if $n_t \geq n_{at}^*$, or in the production of m -goods if $n_t \leq n_{mt}^*$. (b) Under diversification, (sector-efficiency adjusted) factor price equalization will hold and the country's income y_t^{ss} will decrease (increase) with n_t if $\alpha + \beta < (>) \theta + \gamma$, y_t^{ss} will not depend on n_t if labor shares across sectors are the same. (c) Under specialization, y_t^{ss} always rises with n_t .*

A final remark: findings in this section depend mainly on the small economy assumption, the economy's level of development and openness are secondary driving forces. On the one hand, if economies were open but not small, the steady-state relative price of non-agricultural goods would be positively related to the land endowments of the different countries. As a result, the relation between a country's land endowment and its long-run income could be always positive, even in the diversification cone, provided that the country is relatively large (this is shown in appendix C within a two-country world). On the other, it is straightforward that the steady state results would apply to any small-open economy that belongs to the developed world if we consider different land-labor ratios across that group of nations.

4 Income Levels and Convergence Rates

Next, we conduct a numerical experiment to dig deeper on the impact of a country's relative land endowment on its steady-state level of per capita output and speed of convergence. We first calibrate the model parameters. After that, steady-state outcomes for a developing nation with respect to the developed-world economy are computed. Finally, we obtain the asymptotic speed of converge for different values of the land parameter N , which requires a normalized dynamic system. A complete description of this normalization is given in appendix A.

4.1 Calibration

Data on land is obtained from the Food and Agriculture Organization of the United Nations (FAO) for the period 1967 to 1996. The developed-world's land endowment N^* is fixed and normalized to 1. Then, land of the small open economy N can be thought as referring to its relative endowment with respect to the world average.

Regarding the production technology parameters we consider alternative measures of the sectoral income shares that are consistent with the overall factor income shares in GDP. Parente and Prescott (2000) report that a share of capital of 0.25, a land share of 0.05, and a labor share of 0.70 are consistent with the U.S. growth experience. Since the average share of Agriculture in US GDP (net of indirect taxes) over the period 1987-2000 is 2 percent, the following restrictions will determine, respectively, alternative measures of the capital and land shares across sectors:

$$0.02\alpha + 0.98\theta = 0.25, \tag{26}$$

$$0.02\beta + 0.98\gamma = 0.05. \tag{27}$$

Information on the contribution of land to agriculture can be obtained from U.S. Department of Agriculture (USDA) Statistics. Focusing on 1997, non-operator landlords' rents amount to 12,833 millions of current dollars (USDA 2000) and Agricultural GDP net of indirect taxes amounts to 123,042 millions of current dollars, which imply a share of land in agricultural output of 0.10; but this is a lower bound because returns from land owned by producers are not included. We can get a broader estimate of the land return in agriculture using data on cropland (excluding idle cropland), grassland pasture and range used from USDA (2006), and average cash rents per acre of cropland and pasture from USDA (2004). Employing these data, revenues from land become 28,457 millions of dollars. This number, in turn, gives a share of land income in agriculture of 0.23.

Herrendof and Valentinyi (2008) find a smaller interval of values for this parameter: their estimate is 0.11 when they employ purchaser prices, and 0.18 when they use producer prices. Given that results were qualitatively the same for these different β , we choose $\beta = 0.18$, an intermediate value, as the benchmark. Equation (27) then implies that γ equals 0.047.

With respect to the contribution of capital to agriculture and non-agriculture, evidence is mixed. Recent studies suggest that the former is clearly more capital intensive in developed nations. For example, Herrendof and Valentinyi (2008) find that the capital income share in the non-agriculture sector is 0.28, whereas for the agriculture sector is 0.30 if purchaser prices are used and 0.36 if instead producer prices are used. In addition, data from Jorgenson and Stiroh (2000) imply that the average capital share of agriculture in the U.S. economy for the period 1967-1996 is 37.4 percent and 32.8 percent for manufactures plus services. Also, Echevarria (2000) finds a capital share of 43 percent in agriculture for the Canadian economy once the value of land is excluded. Early cross-country studies focusing on the agricultural sector, however, such as Hayami and Ruttan (1985), focusing mainly on developing economies, seem to find smaller capital shares after controlling for the contribution of land. These studies estimate an average share of structures and equipment, which is just a fraction of the capital in agriculture, of around 10 percent.¹⁴

According with this wide range of estimates, we shall consider the following set of capital shares that belong to three general scenarios that provide important qualitative as well as quantitative differences:

$$(\alpha, \theta) = \{(0.1, 0.253), (0.2, 0.251), (0.25, 0.25), (0.3, 0.28), (0.36, 0.28)\}. \quad (28)$$

To obtain the value of θ in this set, we use restriction (26) for α equal or less than 0.25, and estimates in Herrendof and Valentinyi (2008) for α larger than 0.25.

It follows from the chosen input elasticities that agricultural production is more land intensive than non-agricultural production in all possible cases, and that agricultural production will be more capital intensive when $\alpha \geq 0.25$.

We set the growth rate of per capita output equal to two percent, $G_y = 1.02$, the depreciation rate of capital δ to 0.05, the population growth rate to 1.2 percent. Information on relative output prices is obtained from the Economic Report of the president (2004), Table B67. From there, we equalize G_p^* to 1.01 – the average growth rate of the

¹⁴Other authors such as Mundlak *et al.* (1999, 2000) point out that estimates should take into account that capital in agriculture is composed not only of structures and equipment but also of livestock and orchards. Taken both components together, and controlling for the contribution of land, the estimated elasticity of capital in agricultural output by the early studies is between 33 percent and 47 percent.

price index of industrial products relative to farm products for the period 1980-2000 – and fix the steady state (normalized) price to the average price index, $\hat{p}^* = 1.08$. These values of G_y and G_p imply that $G_k = G_y/G_p = 1.0099$.

We still have to give a value to the parameters in the utility function. We set the steady state share of investment in total output equal to the US average for the period 1987-2000, that is $(G_L G_k + \delta - 1) p_t^* k_t^* / y_t^* = 0.21$. This condition, the assumption that the capital income share $r_k^* k_t^* / y_t^*$ is 0.25, and (25) imply a value for the interest rate r_k^* / p^* equal to 0.08, which in turn implies a value for the discount rate ρ equal to 0.98.

With respect to the weight of agricultural-products in consumption, φ , we proceed as follows. Since the U.S. investment share over the period considered was, on average, 0.21, we have that at the steady-state

$$\frac{p_t^* y_{mt}^* l_{mt}^* - p_t^* c_{mt}^*}{y_t^*} = 0.21.$$

Using expression (4) and the market clearing condition for agricultural goods (38), we can rewrite the last equality as

$$\frac{p_t^* y_{mt}^* l_{mt}^*}{y_t^*} - \left(\frac{1 - \varphi}{\varphi} \right) \frac{y_{at}^* l_{at}^*}{y_t^*} = 0.98 - \left(\frac{1 - \varphi}{\varphi} \right) 0.02 = 0.21. \quad (29)$$

This assigns a value of 0.025 to φ . Notice that higher weights of agriculture in total output will be associated with larger values of this parameter. Finally, in all parameter specifications we set the production efficiency parameter B equal to one and solve for the value of the production parameter A that is consistent with the value of \hat{p}^* given above.

4.2 Quantifying long-run income

Remember expression (24): under diversified production, steady-state income in the small-open economy can grow, fall or remain constant with relative land, depending on whether the agricultural sector is less, more, or equally labor intensive than non-agriculture, respectively. These qualitative results are illustrated in Figure 1. The Figure depicts the long run income of the small open economy relative to the developed world average y/y^* against the relative land endowment N . In order to compute y/y^* , we employ the relative normalized income levels \hat{y}/\hat{y}^* defined in appendix A. These two ratios coincide when both economies have the same productivity parameters and population levels, $E_{at} = E_{at}^*$, $E_{mt} = E_{mt}^*$ and $L_t = L_t^*$. This is the particular case depicted in Figure 1.

The Figure shows the diversified production interval between dotted vertical lines in the three cases. Notice that, within this interval, y/y^* is a linear function of land since factor price equalization holds and $l_a = (n_t/n_{at}^* - n_{mt}^*/n_{at}^*) / (1 - n_{mt}^*/n_{at}^*)$. In the top

Figure 1: Long-run income (LHS panels) and consumption (RHS panels) relative to the developed world average as a function of land

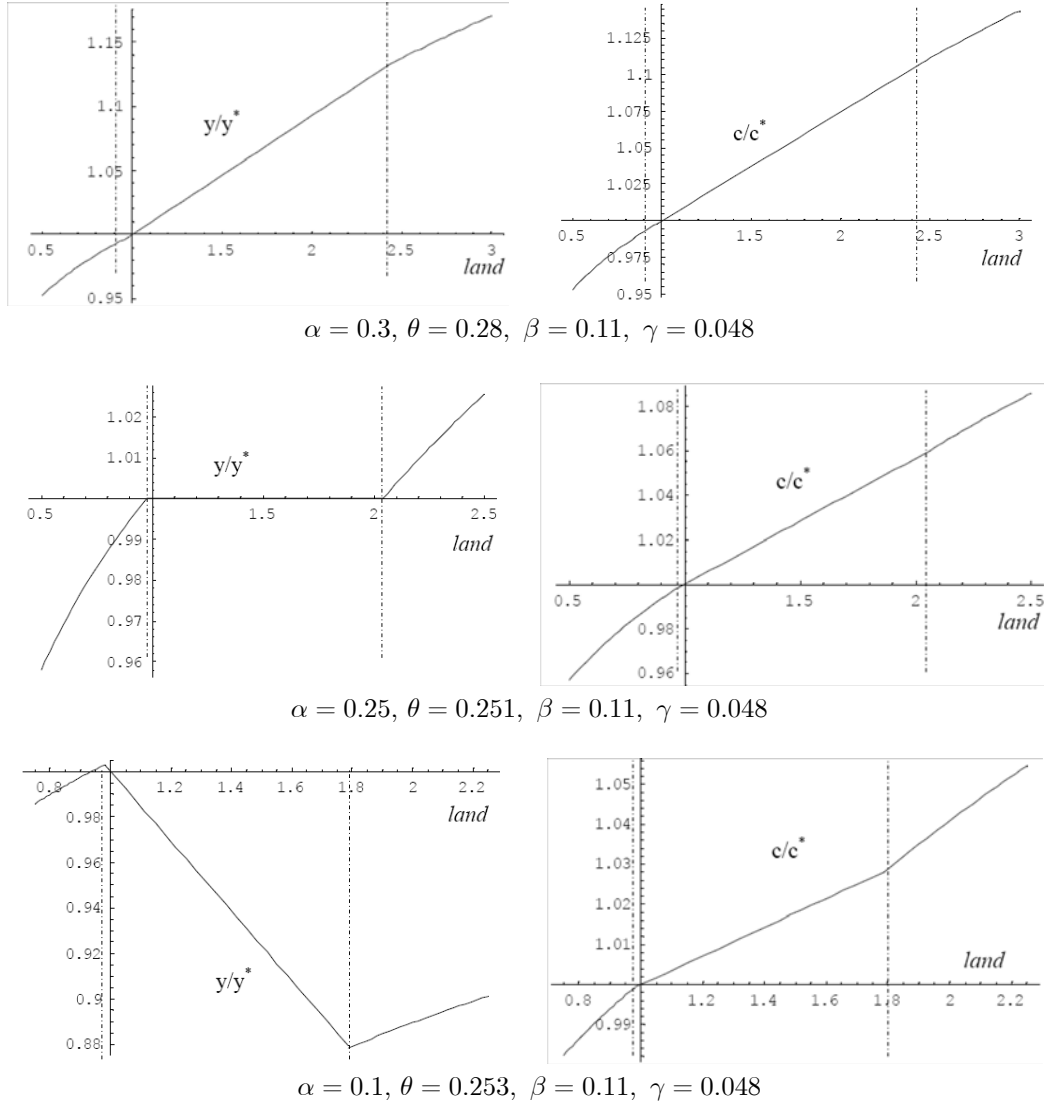


Table 1: Steady-state relative income for different parameterizations, percentage

α	θ	<i>Land, N</i>					
		0.002	0.95	1.25	1.98	2.5	3
0.10	0.253	0.218	1.001	0.997	0.989	0.984	0.978
0.2	0.251	0.203	0.998	1.010	1.040	1.062	1.083
0.25	0.25	0.193	0.996	1.017	1.065	1.099	1.132
0.3	0.28	0.175	0.996	1.020	1.077	1.118	1.157
0.36	0.28	0.159	0.995	1.026	1.104	1.159	1.212

chart of Figure 1, agriculture is less labor intensive and then y/y^* rises with land. In the middle panel, y/y^* remains constant within the diversification interval because agriculture has the same labor share than non-agriculture. Finally, in the bottom chart, y/y^* falls with land under diversification because agriculture is more labor intensive. Outside the diversification interval, the late-bloomer's income equals $AE_{at}^{1-\alpha} n_t^\beta k_t^\alpha$ if $n_t \geq n_{at}^*$, or $p_t^* BE_{mt}^{1-\theta} n_t^\gamma k_t^\theta$ if $n_t \leq n_{mt}^*$, in either case relative income is increasing and concave in n_t .

Figure 1 also shows an interesting feature of the model: steady-state consumption always rises with land. So larger amounts of land imply higher long-run welfare even if income levels are smaller. The reason is that larger amounts of n_t imply lower capital levels when agriculture is less capital intensive than non-agriculture, which lowers steady state savings and investment. This effect on investment is stronger than the effect on income (which depends ultimately on labor intensities) and as a result steady-state consumption rises. In contrast, when agriculture is more capital intensive, both income and investment rise with land, but the effect on income is stronger, so steady state consumption also rises.

To get an idea of the predicted income differences implied by the model, Table 1 gives specific values of y/y^* for the proposed calibration in section 4.1. An important issue is how to proxy N . Given that in the model relative land equals relative land per capita, we take this last ratio as the measure for N . The world's average arable land per capita in FAO statistics equals 0.80 hectares, and ranges from 0.002 to 6.453.¹⁵ There are, however only 2 out of 97 nations with arable land per capita above 2.3 hectares.¹⁶ For this reason, the experiments consider land values between 0.002 and 2.3. Which implies that N goes from 0.002 to 3, since we normalize the world average to 1.

¹⁵We considered arable land, potential arable land, and total area as alternative measures of the land input and found negligible differences in the results. Detailed description of the data used in the paper is provided in the data appendix.

¹⁶These exceptions are Canada and Australia that have an arable land per capita endowment equal to 3.8 and 6.5 hectares, respectively.

Table 2: Speeds of convergence for different parameterizations, percentage

α	θ	<i>Land, N</i>				
		0.95	1.25	1.98	2.5	3
0.1	0.253	7.64	7.81	8.27	8.65	9.06
0.2	0.251	8.69	8.78	8.98	9.12	9.26
0.25	0.25	9.09	9.09	9.09	9.09	9.09
0.3	0.28	7.98	7.89	7.69	7.57	7.46
0.36	0.28	3.74	3.11	2.11	1.65	1.33

Table 1 shows that steady-state income differences among economies that own different land per capita endowments can be substantial, and that they increase with the capital share in the sector that uses the natural input more intensively. More specifically, for $(\alpha, \theta) = (0.1, 0.253)$, income per capita is 4.5 times larger in an economy with $N = 3$ than in an economy with $N = 0.002$; this difference rises and generates a 7.6 fold when $(\alpha, \theta) = (0.36, 0.28)$.

4.3 Quantifying the asymptotic speed of convergence

Next, we study the speed of convergence.¹⁷ Table 2 reports the results for different values of land within the diversification interval for the sets of parameters given in (28). We only focus on the diversification cone because the convergence speed does not depend on N outside it. This is easily deduced from our first interesting finding: the convergence rate is independent of land only if, along the adjustment path, the economy transfers resources between two sectors that have the same capital share ($\alpha = \theta = 0.25$). As a consequence, the convergence speed is independent of land in a specialized economy.

Other interesting results in Table 2 are the following. Predicted values are consistent with convergence rates estimated in the literature, which vary between the 0.4 percent reported by Barro and Sala-i-Martin (1995) and the 10 percent found by Caselli *et al.* (1996). Secondly, when $\alpha > 0.25$ more land generates a lower speed of convergence for given α , and when $\alpha < 0.25$ more land increases the speed of convergence. Thirdly, relative differences in predicted numbers across land-endowment scenarios rise with α . When (α, θ) equals $(0.36, 0.28)$, the largest speed, 3.74, is 2.81 times larger than the lowest, 1.33. This is a very significant, and much bigger difference than the 1.18 discrepancy when (α, θ) is $(0.1, 0.253)$.

¹⁷See appendix A for details. The program was written in Mathematica, and is available from the authors upon request.

Let us give some intuition behind these results. As appendix A shows, the sign of the effect of land on the speed is the *opposite* to the sign of the response of $\partial r_{kt+1}/\partial k_t$ to changes in N . This response, in turn, depends on two main derivatives: $\partial^2 r_{kt+1}/\delta k_{mt+1} \partial N$ and $\partial^2 k_{mt+1}/\delta k_t \partial N$. The sign of the first one can be positive or negative depending on $\alpha - \theta$, and represents a *capital elasticity effect*. More specifically, we know that as the elasticity of capital becomes larger, the return to capital accumulation, that is, the interest rate, falls more slowly along the adjustment path, thus making the speed smaller. In our model, there are two sectors that employ capital. Hence, the *de facto* economy-wide capital elasticity (EWCE) will be affected by the allocation of resources between them. Under perfect competition, the capital elasticity and the capital share coincide. We can then write $EWCE = (\alpha - \theta) s_a + \theta$; where s_a represents the share of agriculture in GDP. Agriculture has a larger land intensity. Hence, s_a will tend to rise with N . As a consequence, the EWCE rises (falls) and the speed falls (rises) with N if $\alpha > \theta$ ($\alpha < \theta$); both remain constant if $\alpha = \theta$.

The derivative $\partial^2 k_{mt+1}/\delta k_t \partial N$ can also be positive or negative depending on α and θ , and represents a *capital accumulation effect*. The accumulation of capital in the non-agriculture sector occurs more slowly (rapidly) as land rises when agriculture (non-agriculture) is more capital intensive. The accumulation effect then goes in the same direction as the capital elasticity effect described above. As a consequence, the effect of N on the speed is negative if $\alpha > \theta$, and positive when $\alpha < \theta$.

Finally, it is worth noting that the dynamic system of a small open developing nation described by equations (53) and (55) in the appendix can also be used to study the dynamics of a small early-bloomer that differs on the land endowment and takes the equilibrium sequence of world prices as given. Therefore, all the qualitative results obtained in this section apply to any small open economy, regardless of its level of development.

The conclusion from the quantitative exercise is that land can have a significant impact on steady-state income and economic growth. Comparing land-scarce and land-abundant nations, the natural input can explain up to a 7-fold in long-run per-capita income and more than a 2-fold in the convergence speed.¹⁸

¹⁸We have analyzed how results change if some parameter values are modified. In particular, we have considered variations in the growth rate of the productivity parameters and population, in the land elasticity, and in the share of agriculture in GDP. Importantly, qualitative findings do not change. With respect to the quantitative ones, a rise in the population growth rate generates negligible variations in relative income, and increases in the speed. A decline in the land elasticity in agriculture reduces the speed, but the effect on long-run relative income is ambiguous. A reduction in the growth rate of non-agricultural prices G_p^* – which can be a consequence of either a fall in the growth rate of E_a or an increase in the one of E_m – produces a rise in the speed of convergence. Finally, as the share of agriculture in GDP rises, relative income does not vary much and the speed slightly increases within the diversification

5 Empirical evidence

Previous results imply that the effect of land per worker on long-run income and transitional growth can be substantial. This section shows that the existence of the two effects can make difficult the interpretation of coefficient signs in growth regressions, and provides some indirect evidence that the effects predicted by the model might be part of the data generating process.¹⁹

5.1 Empirical specification

Let us first derive from the model a simple expression for steady-state output that we can estimate. Equations (21) and (24) imply that the log of national income per capita can be approximated within the diversification cone as:

$$\log y_t = \log \frac{w_t}{1 - \alpha - \beta} + \frac{\beta(\theta + \gamma - \alpha - \beta)}{(1 - \alpha)\gamma - (1 - \theta)\beta} \left[\frac{(1 - \alpha - \beta)\gamma}{(1 - \theta - \gamma)\beta} \frac{n_t}{n_{mt}} - 1 \right]. \quad (30)$$

In (30), income per capita is a function of the wage rate and the ratio n_t/n_{mt} . The wage depends on workers' productivity. The steady-state value of n_{mt} , in turn, depends on a constant relative TFP and on the exogenous price level that is common across economies, by expressions (22) and (37) (see appendix). Hence, under the assumption that cross country differences in workers' productivity and relative TFP (E_{mt}/E_{at}) are well captured by variations in variables that affect TFP, expression (30) provides the following regression for the steady-state level of income per capita in a country i at time t :

$$\log y_{it} = a_o + a_1 \log E_{it} + a_2 n_{it} + u_{it}; \quad (31)$$

where E_{it} represents variables that proxy the economy's aggregate productivity, and u_{it} is an error term. The expression allows land per worker to have a long-run impact on the log of income per capita.

We also want to test whether the land-labor ratio is a potential generator of growth effects. We can write the growth rate of output as a function of the difference between steady-state income and initial income. In particular, from equation (31), we can write:

$$\log y_{it} - \log y_{i,t-1} = b_o + b_1 \log E_{it} + b_2 n_{it} + b_3 \log y_{i,t-1} + \varepsilon_{it}; \quad (32)$$

cones; in addition, because more economies fall under diversified production, income differences between land-abundant and land-scarce economies diminishes.

¹⁹We only test whether land affects income and growth. Ideally, a complete empirical examination of the model predictions should test as well whether the mechanism works through resource reallocations across sectors.

Table 3: Estimation results with simulated data, average across 1000 draws

		level	growth	growth	level	growth	growth
First case:	n	-0.051 (0.011)	-0.059 (0.004)	-0.017 (0.003)	-0.055 (0.002)	-0.058 (0.001)	-0.046 (0.001)
y varies from	log(ini.y)		-0.543 (0.017)	-0.894 (0.023)		-0.958 (0.006)	-1.058 (0.009)
1 to 0.9	n*log(ini.y)			0.181 (0.011)			0.056 (0.004)
Second case:	n	-0.019 (0.011)	-0.021 (0.003)	0.016 (0.002)	0.031 (0.002)	0.030 (0.001)	0.041 (0.001)
y varies from	log(ini.y)		-0.568 (0.015)	-0.873 (0.017)		-0.964 (0.005)	-1.047 (0.009)
1 to 1.1	n*log(ini.y)			0.157 (0.008)			0.043 (0.004)
Third case:	n	0.030 (0.011)	0.030 (0.003)	0.060 (0.003)	0.161 (0.003)	0.139 (0.002)	0.147 (0.004)
y varies from	log(ini.y)		-0.599 (0.013)	-0.846 (0.022)		-0.972 (0.010)	-1.038 (0.026)
1 to 1.4	n*log(ini.y)			0.127 (0.011)			0.034 (0.013)

Coefficients' average standard errors are in parenthesis. Columns 3 to 5 and 6 to 8 show results when income is at 71% and 95% of its adjustment process, respectively.

where ε_{it} is the disturbance term. According to our theory, we expect $b_3 < 0$, but coefficients a_2 and b_2 can take on positive or negative values depending on input elasticities.

It is also possible to include a term to try to separate the long-run and transitional-growth effects of land. We can assume that b_3 is a function of n given that the parameter b_3 in expression (32) is the one most closely related to the convergence speed. We do not have a clear idea of the exact relationship between n and the speed, but in Table 2, this relationship is close to being linear. Let us then assume that $b_3 = b_4 + b_5 n$. Introducing this dependency in (32), we get

$$\log y_{it} - \log y_{i,t-1} = b_o + b_1 \log E_{it} + b_2 n_{it} + b_4 \log y_{i,t-1} + b_5 n_{it} \log y_{it} + \varepsilon_{it}. \quad (33)$$

In (33), b_2 assesses the steady-state level effects of land, whereas coefficient b_5 quantifies its transitional growth effects. Notice that, conditioned on $b_4 < 0$, a negative (positive) effect of n on the convergence speed would imply that $b_5 > (<) 0$.²⁰

5.2 Estimation with simulated data

Theory predicts the possibility of opposing long-run and transitional effects of land. This may create a tension that makes harder finding them in the data with expressions (31)

²⁰A more accurate relation between economic growth and the distance to the steady state is given by

$$\log y_{it} - \log y_{i,t-1} = \lambda (\log y_{it}^* - \log y_{i,t-1});$$

where λ is the convergence speed when output is in log scale. The parameter λ , then, potentially affects the impact of initial income, but also the one of the steady-state determinants. We have estimated (33) with additional interaction terms between n and y^* but found no significant change in the results.

and (32). In principle, regression (33) helps to avoid this problem. However, we do not know the exact relationship between n and the speed. We now use simulated data to get an idea of what we should expect if the impact of land is the one predicted by the model.

The sample size of our artificial data is 80 observations for each variable. Initial income (y_{it-1} in above regressions) randomly takes on 0.6, 0.7, 0.8, 0.9, and 1. We pick the speeds predicted by the $(\alpha, \theta, \beta) = (0.36, 0.28, 0.18)$ case. In particular, n randomly takes on 0.95, 1.25, 1.98, 2.5 and 3, for which the asymptotic speeds are 0.0374, 0.0311, 0.0211, 0.0165 and 0.0133, respectively. We consider three different sets of long-run income values. In all of them, long-run income is a linear function of n , as the theory suggests. In the first one, income falls with n between 1 and 0.9. In the second and third ones, the relationship is positive, with long-run income going from 1 to 1.1 and 1 to 1.4, respectively. For given initial and steady-state income levels, we generate final income levels (y_{it} above) assuming that the asymptotic speed of convergence drives the whole process. Finally, zero-mean random errors with a variance $\sigma_{\varepsilon_{it}}^2 = \text{var}(\log Y_{final})(1 - 0.99)$ are added to final income. The reason for this relatively small error variance is that we want to focus on the potential problems derived from the existence of opposing long-run and transitional effects.

Table 3 provides the outcome of this exercise. The first three and the last three columns of results correspond to a final income value at 75% and 95% of the adjustment process, respectively. We observe that when the level regression estimates the long-run effect of n with relative accuracy, growth specifications pick the same effect with even more accuracy, and the three regressions give similar average values for the n coefficient. The reason is that the impact of diminishing returns on transitional growth is very strong and well captured by initial income. More specifically, the n coefficient in the three regressions give the right information about the steady-state impact when either final income is relatively close to its steady-state value (last three columns), the two effects go in the same direction (first three rows of results), or the long run impact of n is relatively strong compared to its transitional growth one (last three rows of results).

Table 3 also says that the transitional effect of land can be captured. The growth regression that incorporates transitional land components provides a positive coefficient for $\log(\text{initial income}) * n$ all the time, with relatively high accuracy. Remember that this implies an estimated negative impact of land on the speed of convergence. Growth regression (32) can estimate the transitional impact too. This occurs when the economy is not too close to its steady state and the long-run effect of land is relatively small compared to its transitional impact. In particular, when y varies between 1 and 1.1, the

second column of results in Table 3 shows a negative average coefficient for n (-0.016) with a relatively small average standard deviation (0.004). We observe as well, looking at the average estimated coefficients and average standard deviations across draws, that in this case the level regression gives a very similar value for the n coefficient but shows less accuracy. That is, in this scenario, what regressions (31) and (32) interpret as a long-run level impact is actually a transitional growth one.

Another important aspect, not shown in the Table, is that it is possible that neither regression (31) nor regression (32) show accuracy even if land is important to explain the dependent variable when the two effects go in opposite directions. This occurs when the economy is not sufficiently close to the steady state, and the two impacts of land are relatively similar in magnitude.

In sum, we should expect that if both effects go in the same direction, all regressions will capture their sign. However, if they go in different directions, this will create a tension. In this second scenario, regression (31) should provide a significant estimate only if it comes with the right sign. This will occur when final income is relatively close to its steady state or when the long-run impact is relatively strong. Regression (32), in turn, will be able to capture the transitional effect if economies are not very close to their respective steady states, and the effect of land in transitional growth is relatively large. Regression (32) can instead give the long-run impact of land, but then the level regression should provide a similar significant estimate. Finally, regression (33) will be able to discriminate between the two impacts of land if its transitional components are well specified. When this is the case, the estimated land coefficient in regression (33) must not be very different in magnitude to its significant counterpart in regression (31).

5.3 *Data*

We need measures for land, productivity, and income levels across nations. For land, we try three different variables: arable land in use, potential arable land, and total area. The first one is the narrowest and includes only used agricultural land. The second one represents all land that could be potentially employed by agriculture, excluding human settlements. Total land area is the broadest measure and includes any land outside water. As productivity indicators, we introduce in our core regression measures of education, country's openness, and government distortions. These type of variables are among the most important determinants found, for example, by Doppelhofer *et al.* (2004) in cross-country growth regressions. In particular, we use the average educational attainment of

Table 4: Regression results on 80-Country sample

<i>Regression</i> \rightarrow	<i>(31) Levels</i>		<i>(32) Growth rates</i>		<i>(33) Trans effects</i>	
	OLS	GMM	OLS	GMM	OLS	GMM
Arable land (AL)	0.009 (0.038)	-0.061 (0.061)	-0.047* (0.027)	-0.090** (0.040)	0.088 (0.088)	0.163 (0.176)
AL*log(y)					-0.045* (0.026)	-0.076 (0.054)
\dagger R-squ. or Ov. p-val	0.853	0.247	0.595	0.257	0.603	0.315
Potential AL (PAL)	0.004 (0.009)	-0.010 (0.013)	-0.004 (0.008)	-0.014** (0.007)	0.066 (0.055)	0.222*** (0.086)
PAL*log(y)					-0.023 (0.016)	-0.074*** (0.026)
\dagger R-squ. or Ov. p-val	0.853	0.223	0.590	0.130	0.609	0.773
Total area	0.448* (0.244)	-0.301 (0.266)	0.256 (0.363)	-0.434*** (0.159)	4.752*** (1.502)	8.543*** (2.157)
Total area*log(y)					-1.442*** (0.441)	-2.614*** (0.675)
\dagger R-squ. or Ov. p-val	0.860	0.253	0.601	0.230	0.672	0.433

\dagger R-squared in OLS columns, and overidentification-restriction p-value in GMM columns.

African, Latin-American and East Asian dummies, educational attainment, years open, and government consumption included in regressions. Instruments used with GMM, variables, and data sources are described in data appendix. Heteroskedasticity-corrected standard errors are in parentheses.

*** Significantly different from zero at the 1% level. ** Significantly different from zero at the 5% level. * Significantly different from zero at the 10% level.

the labor force, an index of the number of years open to international trade, and the share of government consumption excluding education and defense expenditures. Finally, income levels are approached using the real gross domestic product.

The sample is a cross-section of 80 nations. For each variable and country i , we compute its average value from 1967 to 1996. Exceptions are the income related variables: final income equals $\log y_{i,1996}$, and initial income equals $\log y_{i,1967}$. Variables, sources, descriptive statistics, and nations contained in the sample are described in the data appendix.

Growth empirics suffer from omitted-variable, endogeneity, and error heteroskedasticity problems. We try to control for them. In particular, we control for regional-specific fixed effects introducing in the regression South-Saharan Africa, Latin-America and East-Asia dummies. The three of them are, again, among the most important determinants found by Doppelhofer *et al.* (2004). Variables affected by endogeneity can be schooling, openness, government consumption, and the land-labor ratio. To address this problem, we use GMM estimation having as instruments a set of geographical, climatic, and colonial variables, and the initial value of income (see appendix).²¹

²¹ We follow a standard approach to test whether these instruments (suggested by, for example, Gallup

5.4 Results

Table 4 gives OLS and GMM estimates for land-related coefficients in level and growth regressions with the three different land proxies included one at a time. In the level regressions (first two columns), only total land area is estimated to have a significant effect, in the OLS regression, and this impact is positive. Growth regression (32), in turn, shows land per worker as strongly significant to explain economic growth with the three proxies (3th and 4th columns), especially using the GMM methodology. The estimated negative sign on the growth regression can imply a negative impact of land on the speed of convergence.

Estimated growth effects of land defer when n -related transitional terms are included. Regression (33) (5th and 6th columns) gives positive estimated coefficients for n and negative ones for $n * \log(y_{t-1})$ that, when significant, suggest positive effects of land on long-run income and transitional growth. However, the estimated values are more than 10 times larger than their level regression counterparts. This is clearly indicating a colinearity bias. In particular, there is an extreme correlation between n and $n * \log(y_{t-1})$ that equals 0.98. As a consequence, estimated coefficients are just offsetting each other: one is positive, the other negative, and both relatively large in absolute value.²² According to results obtained with simulated data, this is telling us that regression (33) is not splitting well the two effects, even though land shows power to explain growth. Notice also that the estimated marginal impact of land, $\hat{b}_2 + \hat{b}_5 \log y_{t-1}$, is negative for all income levels in our sample. This reinforces that the land effect on growth that dominates is a negative one.

We have conducted extensive robustness analysis including other variables in the regression such as revolutions and coups, rule of law, life expectancy, malaria prevalence, ethnolinguistic fractionalization, Confucian fraction, and land inequality. Importantly, there is a result that remains robust: significant land coefficients are always positive in level regressions but become always negative in growth regressions.

Taken together in light of the insights provided by estimation with artificial data, our *et al.* 1999, and Bloom *et al.* 2003) are relevant and valid. To assess their relevance, we test for the joint significance of the whole set of external instruments to explain each of the endogenous variables, and find that the p -value is always below 0.000. In addition, some regressions of endogenous variables on the whole set of external instruments give F -statistics equal or larger than 10. The same is true for the other endogenous variables regressed on certain subsets of external instruments. Second, we test as well for overidentifying restrictions with the J -statistic. The latter test is always passed at conventional significance levels. Obviously, even though these tests give statistical support to the exclusion restriction, it can not be completely discarded that the instruments might be affecting income through other variables that are not included in our regression.

²²We have also tried with $\log(n) * \log(y_{t-1})$ and $\log(n * y_{t-1})$ instead of $n * \log(y_{t-1})$, but results were similar in magnitude or coefficients were not significant.

results with the actual numbers suggest opposing effects on land per worker on long-run income and economic growth. More specifically, we find some evidence that land per worker affects positively long-run income, and negatively economic growth. This is consistent with the model predictions.

6 Conclusion

This paper has searched for new roles of land within a dynamic Heckscher-Ohlin model, and have empirically tested its predictions. The model delivers interesting results that occur in small-open economies with diversified production that take international output prices as given. We have found that land affects growth through the convergence speed, and also long-run income. The two impacts can be positive or negative depending on input elasticities, go in opposite directions, and are quantitatively significant. They are driven by *Rybczynski-type* effects as a consequence of the special nature of land and, in particular, of its fixed supply. Interestingly, in the model land and international trade always raise long-run consumption and, therefore, welfare, even when the economy ends up with lower long-run income.

Estimation of income level and growth regressions has given some weak support to these predictions, suggesting that land has a positive effect on long-run per capita income, but affects negatively the speed of convergence. The numerical exercise has shown that these empirical results are consistent with the model predictions if agriculture is more capital intensive, a scenario that does not disagree with the available evidence. This is clearly the case for developed nations. For developing countries, evidence is mixed. While Hayami and Ruttan (1985) suggest that agriculture in less developed areas is less capital intensive, other authors like Mundlak *et al.* (1999, 2000) suggest the opposite.

Besides providing and quantifying new roles of land, our results also contribute to better understand the determinants of the speed of convergence. More standard economic growth frameworks such as Barro and Sala-i-Martin (1995) and Ventura (1997) imply that the convergence speed is only affected by “deep” parameters, like the consumption- and input-substitution elasticities or the discount factor. Our work shows that some variables, like land per worker, can also significantly affect it.

A key implication is that estimated-coefficient signs in growth regressions for variables that can have transitional effects should be interpreted with caution: a negative (positive) coefficient in a growth regression does not necessarily mean that the variable has a negative (positive) effect on long-run income. Therefore, the resource-curse evidence provided by

Sachs and Warner (2001), among others, does not imply that land and other natural resources that are in fixed supply do not contribute positively to long-run income.

Clearly, discriminating accurately between the long-run and transitional effects of these type of variables requires better growth regression specifications. However, as the paper has shown, finding them is no easy task. We leave this important issue to future research.

A The Model's Mathematical Appendix

Proof of Proposition 1. Since land is in (fixed) positive supply it is always profitable to produce positive amounts of at least one good. Suppose production of agricultural goods is positive. Profits in non-agriculture are equal to

$$\Pi_{mt} = p_t B E_{mt}^{1-\theta} K_{mt}^\theta N_{mt}^\gamma L_{mt}^{1-\theta-\gamma} - r_{kt} K_{mt} - r_{nt} N_{mt} - w_t L_{mt}.$$

At the maximum, non-agriculture profits are

$$(p_t B E_{mt}^{1-\theta})^{\frac{1}{1-\theta-\gamma}} \left(\frac{\theta}{r_{kt}}\right)^{\frac{\theta}{1-\theta-\gamma}} \left(\frac{\gamma}{r_{nt}}\right)^{\frac{\gamma}{1-\theta-\gamma}} B E_{mt}^{1-\theta} L_{mt} \left[(1-\theta-\gamma) - w_t \left(\frac{\left(\frac{r_{kt}}{\theta}\right)^\theta \left(\frac{r_{nt}}{\gamma}\right)^\gamma}{p_t B E_{mt}^{1-\theta}} \right)^{\frac{1}{1-\theta-\gamma}} \right] \quad (34)$$

So domestic firms will enter the market for non-agriculture if and only if profits are positive:

$$p_t B E_{mt}^{1-\theta} > \left(\frac{w_t}{1-\theta-\gamma} \right)^{1-\theta-\gamma} \left(\frac{r_{kt}}{\theta} \right)^\theta \left(\frac{r_{nt}}{\gamma} \right)^\gamma \quad (35)$$

Getting the equilibrium prices from the optimality conditions for agricultural goods given in (11), (12) and (13), we obtain expression (14).

Suppose now that production of non-agricultural goods is positive. Following the same steps, it follows that domestic firms will enter the market of agricultural products if and only if profits are positive

$$A E_{at}^{1-\alpha} > \left(\frac{w_t}{1-\alpha-\beta} \right)^{1-\alpha-\beta} \left(\frac{r_{kt}}{\alpha} \right)^\alpha \left(\frac{r_{nt}}{\beta} \right)^\beta \quad (36)$$

Getting the equilibrium prices from the optimality conditions for non-agriculture given in (11), (12) and (13), and changing the direction of inequality, we obtain expression (15).

Proof of Proposition 2. Part (a). Define $A_t = E_{at}^{1-\alpha}/E_{mt}^{1-\theta}$. Let $p^{\min}(k_t; n_t, A_t)$ and $p^{\max}(k_t; n_t, A_t)$ represent the right sides of expressions (14) and (15), respectively. In the steady state diversified production equilibrium, $p^{\min}(k_{at}^*; n_{at}^*, A_t^*) = p^{\max}(k_{mt}^*; n_{mt}^*, A_t^*) = p_t^*$, where $n_{at}^* > n_{mt}^*$ by assumption. Let \underline{k}_t and \bar{k}_t be such that $p^{\min}(\underline{k}_t; n_t, A_t) = p_t^*$ and $p^{\max}(\bar{k}_t; n_t, A_t) = p_t^*$, respectively. That is, $\underline{k}_t = k_{at}^* (n_{at}^*/n_t)^{\frac{\beta-\gamma}{\alpha-\theta}} (A_t^*/A_t)^{\frac{1}{\alpha-\theta}}$ and $\bar{k}_t = k_{mt}^* (n_{mt}^*/n_t)^{\frac{\beta-\gamma}{\alpha-\theta}} (A_t^*/A_t)^{\frac{1}{\alpha-\theta}}$. Note that because $E_{a0} = E_{m0} = E$, $A_t^*/A_t = (E^*/E)^{\theta-\alpha}$. So $\underline{k}_t = k_{at}^* (n_{at}^*/n_t)^{\frac{\beta-\gamma}{\alpha-\theta}} E/E^*$ and $\bar{k}_t = k_{mt}^* (n_{mt}^*/n_t)^{\frac{\beta-\gamma}{\alpha-\theta}} E/E^*$. We can consider the following cases:

(I) If $\alpha \geq \theta$, then $k_{at}^* > k_{mt}^*$. The diversification interval is $(\bar{k}_t, \underline{k}_t)$ when $\alpha > \theta$. When $\alpha = \theta$, the right sides of expressions (14) and (15) do not depend on k ; in this case the result follows directly from Proposition 1.

(I.1) $\alpha > \theta$ and $n_t \in (n_{mt}^*, n_{at}^*) \Rightarrow \bar{k}_t/E < k_{mt}^*/E^* < k_{at}^*/E^* < \underline{k}_t/E$. From Proposition 1, and expressions (14) and (15), $l_{a0} > 0$ and $l_{m0} > 0$ if $\bar{k}_0 < k_0 < k_{m0}^* E/E^*$,

or $l_{m0} = 1$ ($l_{a0} = 0$) if $k_0 \leq \bar{k}_0 < k_{m0}^*E/E^*$. If at the steady state $l_m^{ss} = 1$, then (11) implies $k_t^{ss} = k_{mt}^* (n_t/n_{mt}^*)^{\gamma/(1-\theta)} E/E^*$, but $n_t/n_{mt}^* > 1 \Rightarrow k_t^{ss} > k_{mt}^*E/E^* > \bar{k}_t$, which by proposition 1 would imply $l_a^{ss} = 1$, so $l_m^{ss} = 1$ cannot be optimal. If at the steady state $l_m^{ss} = 0$, then $k_t^{ss} = k_{at}^* (n_t/n_{at}^*)^{\beta/(1-\alpha)} E/E^*$, but $n_t/n_{at}^* < 1 \Rightarrow k_t^{ss} < k_{at}^*E/E^* < \underline{k}_t$, which by proposition 1 would imply $l_a^{ss} = 0$; so $l_m^{ss} = 0$ cannot be optimal. Hence, $l_a^{ss} > 0$ and $l_m^{ss} > 0$ must be optimal. From (11) to (13), (22) and (25) follows that $k_{mt}^{ss} = k_{mt}^*E/E^*$ (see proof of part (b)), and from (16), (17), (18) and (19) that $k_{at}^{ss} = k_{at}^*E/E^*$, $n_{it}^{ss} = n_{it}^* \forall i$ and $k_{mt}^*/E^* < k_t^{ss}/E < k_{at}^*/E^*$.

(I.2) $\alpha > \theta$ and $n_t \geq n_{at}^* \Rightarrow \bar{k}_t < k_{mt}^*E/E^* < \underline{k}_t \leq k_{at}^*E/E^*$ or $\bar{k}_t < \underline{k}_t \leq k_{mt}^*E/E^* < k_{at}^*E/E^*$. So initially $l_{m0} = 1$ if $k_0 \leq \bar{k}_0$; $l_{a0} > 0$ and $l_{m0} > 0$ if $\bar{k}_0 < k_0 < k_{0t}^*E/E^* < \underline{k}_0$, or $\bar{k}_0 < k_0 < \underline{k}_0 < k_{mt}^*E/E^*$; $l_{a0} = 1$ if $\underline{k}_0 \leq k_0 < k_{m0}^*E/E^*$. As before at the steady state $l_m^{ss} = 1$ cannot be optimal; similarly, steady state diversified production, $n_{it}^{ss} = n_{it}^* \forall i$ would imply $n_{mt}^* < n_t < n_{at}^*$ by (8) and (10), which contradicts $n_t \geq n_{at}^*$. So at the steady state $l_a^{ss} = 1$ must be optimal and $k_t^{ss} = k_{at}^* (n_t/n_{at}^*)^{\beta/(1-\alpha)} E/E^* \geq k_{at}^*E/E^*$.

(I.3) $\alpha > \theta$ and $n_t \leq n_{mt}^* \Rightarrow k_{mt}^*E/E^* < k_{at}^*E/E^* < \bar{k}_t < \underline{k}_t$ or $k_{mt}^* < \bar{k}_t < k_{at}^* < \underline{k}_t$. So, in either case, initially $l_{m0} = 1$ since $k_0 < k_{m0}^*E/E^* < \bar{k}_0$. A steady state $l_a^{ss} > 0$ and $l_m^{ss} > 0$ would imply $n_{mt}^* < n_t < n_{at}^*$, which contradicts $n_t \leq n_{mt}^*$. A steady state $l_m^{ss} = 0$ would imply $k_t^{ss} = k_{at}^* (n_t/n_{at}^*)^{\beta/(1-\alpha)} E/E^*$, but $n_t/n_{at}^* < 1 \Rightarrow k_t^{ss} < \underline{k}_t$, so it cannot be optimal. Hence, $l_m^{ss} = 1$ must be optimal and $k_t^{ss} = k_{mt}^* (n_t/n_{mt}^*)^{\gamma/(1-\theta)} E/E^* \leq k_{mt}^*E/E^*$.

(II) If $\alpha < \theta$, then $\tilde{k}_m^* < \tilde{k}_a^*$ or $k_m^* > k_a^*$. The diversification interval is $(\underline{k}_t, \bar{k}_t)$. The next proof follows the same steps as in (I). **(II.1)** $k_{mt}^* < k_{at}^*$. **(II.1a)** $n_t \in (n_{mt}^*, n_{at}^*) \Rightarrow \underline{k}_t < k_{mt}^*E/E^* < \bar{k}_t < k_{at}^*E/E^*$ or $\underline{k}_t < k_{mt}^*E/E^* < k_{at}^*E/E^* < \bar{k}_t$ or $k_{mt}^*E/E^* < \underline{k}_t < \bar{k}_t < k_{at}^*E/E^*$ or $k_{mt}^*E/E^* < \underline{k}_t < k_{at}^*E/E^* < \bar{k}_t$. Initially $l_{m0} = 0$ or $l_{m0} > 0$ and $l_{a0} > 0$; at the steady state $l_m^{ss} = 0 \Rightarrow k_t^{ss} < k_{at}^*E/E^*$ and $k_t^{ss} > \underline{k}_t$ since $n_{at}^*/n_t > 1$ and $\frac{\beta-\gamma}{\theta-\alpha} > \frac{\beta}{1-\alpha}$, so $l_m^{ss} = 0$ cannot be optimal; $l_m^{ss} = 1 \Rightarrow k_t^{ss} > k_{mt}^*E/E^*$ and $k_t^{ss} < \bar{k}_t$, so $l_m^{ss} = 1$ cannot be optimal; so $l_a^{ss} > 0$ and $l_m^{ss} > 0$ and $k_{at}^*E/E^* < k_t^{ss} < k_{mt}^*E/E^*$. **(II.1b)** $n_t \geq n_{at}^* \Rightarrow k_{mt}^*E/E^* < k_{at}^*E/E^* < \underline{k}_t < \bar{k}_t$. Initially $l_{m0} = 0$; at the steady state $l_a^{ss} > 0$ and $l_m^{ss} > 0 \Rightarrow n_t < n_{at}^*$, which is false; $l_m^{ss} = 1 \Rightarrow k_{mt}^*E/E^* < k_t^{ss} < \underline{k}_t$, so $l_m^{ss} = 1$ cannot be optimal; $l_m^{ss} = 0$ is optimal and $k_{at}^*E/E^* \leq k_t^{ss} < \underline{k}_t$. **(II.1c)** $n_t \leq n_{mt}^* \Rightarrow \underline{k}_t < \bar{k}_t < k_{mt}^*E/E^* < k_{at}^*E/E^*$. Initially, $l_{m0} = 0$ or $l_{m0} > 0$ and $l_{a0} > 0$ or $l_{m0} = 1$. At the steady state $l_a^{ss} > 0$ and $l_m^{ss} > 0 \Rightarrow n_t > n_{mt}^*$, which is false; $l_m^{ss} = 0 \Rightarrow k_t^{ss} < k_{at}^*E/E^*$ and $k_t^{ss} > \underline{k}_t$, so $l_m = 0$ cannot be optimal; so $l_m = 1$ is optimal and $\bar{k}_t < k_t^{ss} \leq k_{mt}^*E/E^*$.

(II.2) $k_{at}^* < k_{mt}^*$. The next proof follows the same steps as in (II.1). **(II.2a)** $n \in (n_m^*, n_a^*) \Rightarrow \underline{k}_t < k_{at}^*E/E^* < k_{mt}^*E/E^* < \bar{k}_t$, so steady state equilibrium implies $l_a^{ss} > 0$ and $l_m^{ss} > 0$ with $k_{at}^*E/E^* < k_t^{ss} < k_{mt}^*E/E^*$. **(II.2b)** $n_t \geq n_{at}^* \Rightarrow k_{at}^*E/E^* < \underline{k}_t < k_{mt}^*E/E^* < \bar{k}_t$ or $k_{at}^*E/E^* < k_{mt}^*E/E^* < \underline{k}_t < \bar{k}_t$, so $l_m^{ss} = 0$ and $k_{at}^*E/E^* \leq k_t^{ss} < \underline{k}_t$. **(II.2c)** $n_t \leq n_{mt}^* \Rightarrow \underline{k}_t < k_{at}^*E/E^* < \bar{k}_t < k_{mt}^*E/E^*$ or $\underline{k}_t < \bar{k}_t < k_{at}^* < k_{mt}^*$, so $l_m^{ss} = 1$ and $\bar{k}_t < k_t^{ss} \leq k_{mt}^*E/E^*$.

Part (b). Equation (25) implies that $r_{kt} = r_{kt}^*$ in all nations at steady state. Under steady state diversified production equilibrium, equations (11) to (13), (22) and (25) imply

that, in the long-run

$$\frac{k_{mt}^{ss}}{E_{mt}} = \left[p_t^* \frac{B}{A} \left(\frac{E_{mt}}{E_{at}} \right)^{1-\alpha} \left(\frac{\theta}{\alpha} \right)^\alpha \left(\frac{1-\theta-\gamma}{1-\alpha-\beta} \right)^{1-\alpha-\beta} \left(\frac{\gamma}{\beta} \right)^\beta \left(\frac{\theta}{G_k \rho^{-1} + \delta - 1} \right)^{\frac{\beta-\gamma}{\gamma}} \right]^{\frac{\gamma}{(1-\theta)\beta - (1-\alpha)\gamma}}. \quad (37)$$

Hence, because in each sector technical progress occurs at the same rate in all countries, $k_{mt}^{ss}/E_{mt} = k_{mt}^*/E_{mt}^*$. (16) and (17) $\Rightarrow k_{at}^{ss}/E_{at} = k_{at}^*/E_{at}^*$ and $w_t^{ss}/E_{it} = w_t^*/E_{it}^*$, $i = a, m$. (18), (19) and (22) $\Rightarrow n_{it}^{ss} = n_{it}^*$ and so $r_{nt}^{ss}/E_{it} = r_{nt}^*/E_{it}^*$, $i = a, m$. So sector-efficiency-adjusted factor price equalization holds.

Part (c) follows directly from (24), (6) and (7).

The world economy Assume that all developed countries are at steady state and share the same endowments. So the equilibrium for the developed world economy will be the same as the equilibrium for a single large and closed economy, and it will not be affected by the behavior of the small (still developing) country. Then the world market clearing conditions for final goods are

$$c_{at} = l_{at} y_{at} = A E_{at}^{1-\alpha} l_{at}^\alpha k_{at}^\beta n_{at}^\beta, \quad (38)$$

$$c_{mt} + x_t = l_{mt} y_{mt} = B E_{mt}^{1-\theta} l_{mt}^\theta k_{mt}^\theta n_{mt}^\gamma, \quad (39)$$

where $y_{it} = Y_{it}/L_{it}$. In equilibrium, the world economy will produce positive amounts of both goods. An expression for x_t can be obtained using (38) and (39): $x_t = \frac{Y_{mt}}{L_t} - c_{mt} = \frac{Y_{mt}}{L_t} - \left(\frac{c_{mt}}{c_{at}} \right) \frac{Y_{at}}{L_t}$. Then using (4), $x_t = y_{mt} l_{mt} - \left(\frac{1-\varphi}{\varphi p_t} \right) y_{at} l_{at}$. Finally, using (11), we can write output as a function of the interest rate and capital, the resulting expression along with (16) and (17) imply that

$$x_t = \frac{r_{kt}}{p_t} k_{mt} \left[\left(\frac{l_{mt}}{\theta} \right) - \left(\frac{1-\varphi}{\varphi} \right) \frac{(1-\theta-\gamma)\alpha}{\theta(1-\alpha-\beta)} \left(\frac{l_{at}}{\alpha} \right) \right]. \quad (40)$$

Conditions (11), (12) and (13) imply that the price of non-agricultural goods is

$$p_t = \frac{A E_{at}^{1-\alpha}}{B E_{mt}^{1-\theta}} \left(\frac{\alpha}{\theta} \right)^\alpha \left(\frac{\beta}{\gamma} \right)^\beta \left(\frac{1-\alpha-\beta}{1-\theta-\gamma} \right)^{1-\alpha-\beta} k_{mt}^{\alpha-\theta} n_{mt}^{\beta-\gamma}. \quad (41)$$

Condition (25) and equations (3) and (40) imply that, at the steady state

$$k_t^* = k_{mt}^* \left(\frac{G_k^* \rho^{-1} + \delta - 1}{G_L G_k^* + \delta - 1} \right) \left[\frac{l_m^*}{\theta} - \left(\frac{1-\varphi}{\varphi} \right) \frac{(1-\theta-\gamma)\alpha}{\theta(1-\alpha-\beta)} \frac{l_a^*}{\alpha} \right],$$

where G_k^* is the gross growth rate of capital per capita along the balanced-growth path defined in the next section. Substituting (20) for k_t^* in the last expression, k_{mt}^* cancels out in both sides. Then, using (8), we find that l_{mt}^* , and so $l_{at}^* = 1 - l_m^*$, does not depend on land:

$$l_m^* = \frac{\frac{(1-\theta-\gamma)\alpha}{\theta(1-\alpha-\beta)} \left[1 + \left(\frac{1-\varphi}{\alpha\varphi} \right) \frac{G_k^* \rho^{-1} + \delta - 1}{G_L G_k^* + \delta - 1} \right]}{\frac{G_k^* \rho^{-1} + \delta - 1}{\theta(G_L G_k^* + \delta - 1)} - 1 + \frac{(1-\theta-\gamma)\alpha}{\theta(1-\alpha-\beta)} \left[1 + \left(\frac{1-\varphi}{\alpha\varphi} \right) \frac{G_k^* \rho^{-1} + \delta - 1}{G_L G_k^* + \delta - 1} \right]}. \quad (42)$$

Substituting (42) into (21) we can solve for n_{mt}^* and then use (22) and (25) to get k_{mt}^* . Expressions for n_{at}^* and k_{at}^* follow from conditions (16) to (19). Substituting k_{mt}^* and l_m^*

into (20) yields k_t^* , and substituting k_{mt}^* and n_{mt}^* into (41) yields p_t^* . Note that (21) and (20) then imply that the ratios k_t^*/k_{mt}^* and n_t^*/n_{mt}^* are constant and independent of n_t . So, for a proportional change dn/n , it follows from (22) and (20) that $dk/k = dk_m^*/k_m^* = [\gamma/(1-\theta)] dn_m^*/n_m^* = [\gamma/(1-\theta)] dn/n$. And from (43) that $dp^*/p^* = \frac{\beta(1-\theta)-\gamma(1-\alpha)}{1-\theta} dn/n$. Therefore, in the closed economy larger amounts of land have always positive effects on the stock of capital and on total output.

From (42), we can obtain the rest of the world's steady state equilibrium variables. Note that the world's capital k_t^* is always positively related to the world's relative endowment of land n_t^* , but that p_t^* can be increasing or decreasing in n_t^* depending on the relative use of land across sectors. Using (41) we find that:

$$p_t^* = \frac{\frac{A}{B} \left(\frac{E_{at}^*}{E_{mt}^*} \right)^{1-\alpha} \left(\frac{\alpha}{\theta} \right)^\alpha \left(\frac{\beta}{\gamma} \right)^\beta \left(\frac{1-\alpha-\beta}{1-\theta-\gamma} \right)^{1-\alpha-\beta} \left(\frac{\theta}{G_k^* \rho^{-1} + \delta - 1} \right)^{\frac{\alpha-\theta}{1-\alpha}} n_t^{*\frac{\beta(1-\theta)-\gamma(1-\alpha)}{1-\theta}}}{\left(\frac{(1-\theta-\gamma)\beta}{(1-\alpha-\beta)\gamma} + l_m^* \left(1 - \frac{(1-\theta-\gamma)\beta}{(1-\alpha-\beta)\gamma} \right) \right)^{\frac{\beta(1-\theta)-\gamma(1-\alpha)}{1-\theta}}} n_t^*, \quad (43)$$

where l_m^* is given by (42). Regarding the convergence speed for the developed world, it can be shown that equilibrium conditions imply that the Jacobean matrix of the normalized dynamic system at the steady state does not depend on n_t , hence the convergence speed of the closed economy is independent of land.

Steady-state growth, normalized variables, and the equation system Growth rates along the balanced growth path in the developed world and the developing country coincide. In particular, equilibrium conditions (8) to (10) imply that $G_{l_a}^* = G_{l_m}^* = 0$, $G_{k_a}^* = G_{k_m}^* = G_k^* = G_x^*$ and that $G_{n_a}^* = G_{n_m}^* = G_n^* = G_L^{-1}$. Expression (23) says that $G_y^* = G_{y_a}^* = G_p^* G_{y_m}^*$. Budget constraint (2) and equation (3) imply, in turn, the following steady-state conditions: $G_c^* = G_{c_a}^* = G_p^* G_{c_m}^* = G_p^* G_x^* = G_p^* G_k^* = G_{r_n}^* G_L^{-1} = G_w^*$, and $G_{r_k}^* = G_p^*$. This and production functions (6) and (7) give the growth rate for output and prices as $G_y^* = G_{E_a}^{1-\alpha} G_{E_m}^\alpha G_L^{-[\beta+\alpha\gamma/(1-\theta)]}$ and $G_p^* = \left[(G_{E_a}/G_{E_m}) G_L^{\gamma/(1-\theta) - \beta/(1-\alpha)} \right]^{1-\alpha}$, respectively.

In order to obtain an equation system composed of variables that reach constant values at steady state, we carry out the following normalization suggested by the previous paragraph. We define $\hat{z} = \frac{z}{E_a} (pL^\beta)^{1/(1-\alpha)}$, for $z = k, y_m, c_m, x, k_m, k_a$. Let us also define $\hat{v} = \frac{v}{E_a} (p^\alpha L^\beta)^{1/(1-\alpha)}$, for $v = y, c_a, y_a, c, w$. Finally, $\hat{p} = p / [(E_a/E_m) L^{\gamma/(1-\theta) - \beta/(1-\alpha)}]^{1-\alpha}$.

The system of equations that characterizes equilibria is composed of equations (2) to (5), (11), (13), (20), (21), (24), (38), (39) and (41) for the developed world, taking G_L , G_{E_a} , G_{E_m} , N , and $E_{m_0} = E_{a_0} = E$ as given. For the developing nation that takes international product prices as given, the equation system is the same except that expressions (4), (38) and (39) are not needed, and the evolution of p is exogenously given by G_p^* .

In terms of the normalized variables, the above system for the developed world can be written as:

$$\frac{\hat{c}_{t+1}}{\hat{c}_t} = \frac{\left(G_{p_t} G_L^\beta \right)^{\frac{1}{1-\alpha}}}{G_{E_a}} \rho(\hat{r}_{kt+1} + 1 - \delta), \quad \text{with } \hat{r}_{kt} = \theta \hat{p}_t^{\frac{1-\theta}{1-\alpha}} \hat{k}_{mt}^{\theta-1} \left(\frac{N_{mt}}{l_{mt}} \right)^\gamma, \quad (44)$$

$$\text{and } G_{p_t} = \frac{\hat{p}_{t+1}}{\hat{p}_t} \left(\frac{G_{E_a} G_L^{\frac{\gamma}{1-\theta} - \frac{\beta}{1-\alpha}}}{G_{E_m}} \right)^{\frac{1}{1-\alpha}}; \quad (45)$$

$$\hat{k}_{t+1} = \left(\frac{G_{p_t}}{G_L^{1-\alpha-\beta}} \right)^{\frac{1}{1-\alpha}} G_{E_a}^{-1} [(1-\delta)\hat{k}_t + \hat{x}_t]; \quad (46)$$

$$\frac{\hat{w}_t \left[1 + l_{mt} \left(\frac{\theta + \gamma - \alpha - \beta}{1 - \theta - \gamma} \right) \right]}{1 - \alpha - \beta} = \hat{c}_t + \hat{x}_t, \text{ with } \hat{w}_t = (1 - \theta - \gamma) B \hat{p}_t^{\frac{1-\theta}{1-\alpha}} \hat{k}_{mt}^{\theta} \left(\frac{N_{mt}}{l_{mt}} \right)^{\gamma}; \quad (47)$$

$$\hat{k}_t = \hat{k}_{mt} \left[(1 - l_{mt}) \left(\frac{\alpha}{\theta} \right) \frac{1 - \theta - \gamma}{1 - \alpha - \beta} + l_{mt} \right]; \quad (48)$$

$$N l_{mt} = N_{mt} \left[(1 - l_{mt}) \left(\frac{\beta}{\gamma} \right) \frac{1 - \theta - \gamma}{1 - \alpha - \beta} + l_{mt} \right]; \quad (49)$$

$$\hat{p}_t = \left[\frac{A}{B} \left(\frac{\alpha}{\theta} \right)^{\alpha} \left(\frac{\beta}{\gamma} \right)^{\beta} \left(\frac{1 - \alpha - \beta}{1 - \theta - \gamma} \right)^{1-\alpha-\beta} \hat{k}_{mt}^{\alpha-\theta} \left(\frac{N_{mt}}{l_{mt}} \right)^{\beta-\gamma} \right]^{\frac{1-\alpha}{1-\theta}}; \quad (50)$$

$$\frac{(1 - \theta - \gamma)(1 - l_{mt})}{(1 - \alpha - \beta) \left(l_{mt} - \frac{\theta \hat{x}_t}{\hat{r}_{kt} \hat{k}_{mt}} \right)} = \frac{\varphi}{1 - \varphi}; \quad (51)$$

$$\text{and } G_L, G_{E_a}, G_{E_m}, E \text{ given.} \quad (52)$$

And for the developing economy as (44), (46) to (50), (52), $G_{p_t} = G_{p_t}^*$, and $\hat{p}_t = \hat{p}^* (L_t^*/L_t)^{\gamma(1-\alpha)/(1-\theta)-\beta}$ taken as given. Since population grows everywhere at the same rate, without loss of generality we assume $L_t^*/L_t = 1$.

The asymptotic speed of convergence For the developing economy, for which $\hat{p}_t = \hat{p}^*$, equations (44) and (50) obtain the following Euler equation for normalized consumption under diversified production:

$$\hat{c}_{t+1} = \hat{c}_t G_{E_m}^{-1} G_L^{\frac{\gamma}{1-\alpha}} \rho \left[\theta B v_{t+1}^* \hat{k}_{mt+1}^{\frac{\gamma(1-\alpha)-\beta(1-\theta)}{\beta-\gamma}} + 1 - \delta \right]; \quad (53)$$

where $v_t^* = \left[\frac{B}{A} \left(\frac{\theta}{\alpha} \right)^{\alpha} \left(\frac{\gamma}{\beta} \right)^{\beta} \left(\frac{1-\theta-\gamma}{1-\alpha-\beta} \right)^{1-\alpha-\beta} (\hat{p}_t^*)^{\frac{1-\theta}{1-\alpha}} \right]^{\frac{\gamma}{\beta-\gamma}} (\hat{p}_t^*)^{\frac{1-\theta}{1-\alpha}}$; and given $\hat{p}_t^* = \hat{p}^*$, $\hat{k}_{mt+1} = \hat{k}_m(\hat{k}_{t+1}, N)$ is the implicit solution to

$$\left(\frac{v_t^*}{(\hat{p}_t^*)^{\frac{1-\theta}{1-\alpha}}} \right)^{\frac{1}{\gamma}} \hat{k}_{mt}^{\frac{\theta-\alpha}{\beta-\gamma}} = \frac{N}{\frac{\gamma(1-\alpha)-\beta(1-\theta)}{\theta(1-\beta)-\alpha(1-\gamma)} \frac{\theta}{\gamma} \left(\frac{\hat{k}_t}{\hat{k}_{mt}} - \frac{\alpha(1-\theta-\gamma)}{\theta(1-\alpha-\beta)} \right) + \frac{\beta(1-\theta-\gamma)}{\gamma(1-\alpha-\beta)}}. \quad (54)$$

Expression (54) comes from combining (48) to (50). This implicit function implies that $\hat{r}_{kt+1} = \theta B v_{t+1}^* \hat{k}_{mt+1}^{[\gamma(1-\alpha)-\beta(1-\theta)]/(\beta-\gamma)} = r_k(\hat{k}_{mt+1})$ around the steady state equilibrium is decreasing in \hat{k}_{t+1} , and increasing (decreasing) in N if $\hat{k}_{at}^* > \hat{k}_{mt}^*$ ($\hat{k}_{at}^* < \hat{k}_{mt}^*$).

From equations (46) to (48), and (50), the law of motion for normalized capital per worker is

$$\hat{k}_{t+1} = G_{E_m}^{-1} G_L^{\frac{\gamma}{1-\theta}-1} \left[\hat{y}_t - \hat{c}_t + (1 - \delta) \hat{k}_t \right], \quad (55)$$

where, under diversified production, normalized income is

$$\hat{y}_t = Bv_t^* \hat{k}_{mt}^{\frac{\beta\theta - \gamma\alpha}{\beta - \gamma}} \left[\frac{1 - \theta - \gamma}{1 - \alpha - \beta} + \frac{\theta(\alpha + \beta - \theta - \gamma)}{\alpha(1 - \gamma) - \theta(1 - \beta)} \left(\frac{\hat{k}_t}{\hat{k}_{mt}} - \frac{\alpha(1 - \theta - \gamma)}{\theta(1 - \alpha - \beta)} \right) \right]. \quad (56)$$

As in previous literature, we next linearize the dynamic system described by expressions (53) and (55) around the steady state to get $\hat{c}_{t+1} = \Phi(\hat{k}_t, \hat{c}_t; N)$ and $\hat{k}_{t+1} = \Psi(\hat{k}_t, \hat{c}_t; N)$. The asymptotic speed of convergence in our discrete time model is given by

$$-\frac{(G_y^* \hat{y}_{t+1} - \hat{y}_t) - (G_y^* \hat{y}^{ss} - \hat{y}^{ss})}{\hat{y}_t - \hat{y}^{ss}} = 1 - \lambda G_y^*, \quad (57)$$

where λ is the stable root of the linearized dynamic system associated to equations (53) and (55) under diversified production. This exercise also reveals that the transition is characterized by a one-dimensional stable saddle-path, which in turn implies that the adjustment path is asymptotically stable and unique.

The linearization around the steady state equilibrium implies that $\lambda = \frac{1}{2}(\Psi_k^* + \Phi_c^* - \Delta^{1/2})$, with $\Delta = (\Psi_k^* - \Phi_c^*)^2 + 4\Psi_c^* \Phi_k^*$, where the subscripts stand for partial derivatives and the asterisk means steady state value. In a diversified production equilibrium Ψ_c^* does not depend on N , but Ψ_k^* , Φ_c^* and Φ_k^* do. In all numerical experiments: $\Delta > 0$, $2 > \Psi_k^* > \Phi_c^* > 1$, $\Psi_c^* < 0$, $\Phi_k^* < 0$; Ψ_k^* , Φ_c^* and Φ_k^* are monotone functions of N , $\Psi_{kn}^* > 0$, $\text{sign}(\Phi_{kn}^*) = -\text{sign}(\Phi_{cn}^*)$, $\Phi_{kn}^* > 0$ if $\alpha > \theta$, $\Phi_{kn}^* < 0$ if $\alpha < \theta$. If $\alpha = \theta$, $\Psi_{kn}^* = \Phi_{cn}^* = \Phi_{kn}^* = 0$. The slope of the saddle path at the steady state is $(\Psi_k^* - \lambda)/(-\Psi_c^*)$. The effect of N on λ can be written as

$$\lambda_n = \frac{1}{2} \left[\left(1 - \frac{\Psi_k^* - \Phi_c^*}{\Delta^{1/2}} \right) \Psi_{kn}^* + \left(1 + \frac{\Psi_k^* - \Phi_c^*}{\Delta^{1/2}} \right) \Phi_{cn}^* \right] - \frac{\Psi_c^*}{\Delta^{1/2}} \Phi_{kn}^*. \quad (58)$$

In all numerical examples the sign of this derivative coincides with the sign of Φ_{kn}^* , which in turn is driven by the sign of $\partial^2 \hat{r}_{kt+1} / \partial \hat{k}_t \partial N$ evaluated at the steady state:

$$\frac{\partial^2 \hat{r}_{kt+1}}{\partial \hat{k}_t \partial N} = r_k'' \frac{\partial \hat{k}_{mt+1}}{\partial N} \frac{\partial \hat{k}_{mt+1}}{\partial \hat{k}_t} + r_k' \frac{\partial^2 \hat{k}_{mt+1}}{\partial \hat{k}_t \partial N} > 0 (< 0) \text{ if } \alpha > \theta (\alpha < \theta), \quad (59)$$

where $r_k' < 0$ and $r_k'' > 0$ represent, respectively, the first and second derivatives of the function $r_k(k_{mt+1})$ defined right below (54), $\frac{\partial \hat{k}_{mt+1}}{\partial \hat{k}_t} > 0$, $\frac{\partial^2 \hat{k}_{mt+1}}{\partial \hat{k}_t \partial N} < 0$ and $\frac{\partial \hat{k}_{mt+1}}{\partial N} < 0$ if $\alpha > \theta$, $\frac{\partial^2 \hat{k}_{mt+1}}{\partial \hat{k}_t \partial N} > 0$ and $\frac{\partial \hat{k}_{mt+1}}{\partial N} > 0$ if $\alpha < \theta$. The first term $r_k'' \frac{\partial \hat{k}_{mt+1}}{\partial N} \frac{\partial \hat{k}_{mt+1}}{\partial \hat{k}_t} = \partial^2 r_{kt+1} / \partial k_{mt+1} \partial N$ relates to what we have called the capital elasticity effect of land, and the second relates to the capital accumulation effect. From (57) the effect of land on the speed of convergence is given by $-\lambda_n G_y^*$, so the sign of $-\frac{\partial^2 \hat{r}_{kt+1}}{\partial \hat{k}_t \partial N}$ drives the negative or positive response of the speed of convergence to an increase in the land endowment.

B Service sector

In the model, all products are tradable. This is true, in general, for agricultural and manufacturing products. Services are, however, less tradable. Lipsey (2006), for example,

reports that trade in services is around one forth of total world-wide trade in goods, and that for the U.S. it represents 40 percent and 20 percent of total exports and imports, respectively. Comparing these numbers to a share of services in GDP of around 65% for the world and 75% for the U.S. (UNCTAD statistics), it is clear that trade in services, although significant, occurs at a lower scale than in other sectors. This section studies how the introduction of the tertiary activity can affect our results.

Denote the service sector with a subindex s and provide technologies and variables related to this sector with interpretations and assumptions equivalent to the ones made for agriculture and non-agriculture. Also assume that the technologies and variables related to non-agriculture belong now to manufacturing. In addition, consider that preferences are

$$\sum_{t=0}^{\infty} \rho^t L_t [\varphi_a \ln c_{at} + \varphi_m \ln c_{mt} + (1 - \varphi_a - \varphi_m) \ln c_{st}], \quad (60)$$

and the household's budget constraint is

$$c_{at} + p_{mt}(c_{mt} + x_t) + p_{st}c_{st} = r_{kt}k_t + r_{nt}n_t + w_t, \quad (61)$$

where p_{mt} and p_{st} are the price of manufacturing goods and services, respectively. Production of services is possible according to:

$$Y_{st} = E_{st}^{1-\lambda} K_{st}^{\lambda} N_{st}^{\mu} L_{st}^{1-\lambda-\mu} = E_{st}^{1-\lambda} L_{st} k_{st}^{\lambda} n_{st}^{\mu}, \quad \lambda, \mu, \lambda + \mu \in (0, 1). \quad (62)$$

We assume that production in the other two sectors is given by (6) and (7), and that agriculture is still the most land intensive, $\mu < \beta$.

Equilibrium conditions (8) to (10) become:

$$l_{at} + l_{mt} + l_{st} = 1, \quad (63)$$

$$l_{at}k_{at} + l_{mt}k_{mt} + l_{st}k_{st} = k_t, \quad (64)$$

$$l_{at}n_{at} + l_{mt}n_{mt} + l_{st}n_{st} = n_t. \quad (65)$$

And equilibrium in goods markets now require:

$$c_{at} + p_{mt}(c_{mt} + x_t) = l_{at}y_{at} + p_{mt} l_{mt}y_{mt}, \quad (66)$$

$$c_{st} = l_{st}y_{st}. \quad (67)$$

Maximizing (60) subject to (61) gives:

$$\left(\frac{\varphi_a}{c_{at}} \right) p_{mt} = \frac{\varphi_m}{c_{mt}} = \left(\frac{1 - \varphi_a - \varphi_m}{c_{st}} \right) \frac{p_{mt}}{p_{st}}, \quad (68)$$

and

$$\frac{c_{t+1}}{c_t} = \frac{p_{m,t+1}}{p_{mt}} \rho \left(\frac{r_{kt+1}}{p_{m,t+1}} + 1 - \delta \right), \quad (69)$$

where $c_t = c_{at} + p_{mt}c_{mt} + p_{st}c_{st}$.

Profit maximization by firms, in turn, gives:

$$r_{kt} = \alpha E_{at}^{1-\alpha} k_{at}^{\alpha-1} n_{at}^{\beta} = p_{mt} \theta E_{mt}^{1-\theta} k_{mt}^{\theta-1} n_{mt}^{\gamma} = p_{st} \lambda E_{st}^{1-\lambda} k_{st}^{\lambda-1} n_{st}^{\mu}, \quad (70)$$

$$r_{nt} = \beta E_{at}^{1-\alpha} k_{at}^{\alpha} n_{at}^{\beta-1} = p_{mt} \gamma E_{mt}^{1-\theta} k_{mt}^{\theta} n_{mt}^{\gamma-1} = p_{st} \mu E_{st}^{1-\lambda} k_{st}^{\lambda} n_{st}^{\mu-1}, \quad (71)$$

$$w_t = (1-\alpha-\beta) E_{at}^{1-\alpha} k_{at}^{\alpha} n_{at}^{\beta} = p_{mt} (1-\theta-\gamma) E_{mt}^{1-\theta} k_{mt}^{\theta} n_{mt}^{\gamma} = p_{st} (1-\lambda-\mu) E_{st}^{1-\lambda} k_{st}^{\lambda} n_{st}^{\mu} \quad (72)$$

Combining equations (61) to (65), and (68) to (72) following the same logic as for the two sector model, we obtain

$$\frac{w_t}{1-\alpha-\beta} \left[1 + l_{mt} \left(\frac{\theta + \gamma - \alpha - \beta}{1 - \theta - \gamma} \right) + l_{st} \left(\frac{\lambda + \mu - \alpha - \beta}{1 - \lambda - \mu} \right) \right] = c_t + p_{mt}x_t, \quad (73)$$

$$k_t = k_{mt} \left[(1 - l_{mt} - l_{st}) \frac{\alpha(1 - \theta - \gamma)}{\theta(1 - \alpha - \beta)} + l_{mt} + l_{st} \frac{\lambda(1 - \theta - \gamma)}{\theta(1 - \lambda - \mu)} \right], \quad (74)$$

$$n_t = n_{mt} \left[(1 - l_{mt} - l_{st}) \frac{\beta(1 - \theta - \gamma)}{\gamma(1 - \alpha - \beta)} + l_{mt} + l_{st} \frac{\mu(1 - \theta - \gamma)}{\gamma(1 - \lambda - \mu)} \right], \quad (75)$$

$$p_{mt} = \frac{A}{B} \frac{E_{at}^{1-\alpha}}{E_{mt}^{1-\theta}} \left(\frac{\alpha}{\theta} \right)^\alpha \left(\frac{\beta}{\gamma} \right)^\beta \left(\frac{1 - \alpha - \beta}{1 - \theta - \gamma} \right)^{1-\alpha-\beta} k_{mt}^{\alpha-\theta} n_{mt}^{\beta-\gamma}, \quad (76)$$

and

$$p_{st} = A \frac{E_{at}^{1-\alpha}}{E_{st}^{1-\lambda}} \left(\frac{\alpha}{\lambda} \right)^\alpha \left(\frac{\beta}{\mu} \right)^\beta \left(\frac{1 - \alpha - \beta}{1 - \lambda - \mu} \right)^{1-\alpha-\beta} k_{st}^{\alpha-\theta} n_{st}^{\beta-\gamma}. \quad (77)$$

Equations (3), (69), (70), and (72) to (77) form the system that characterizes the equilibrium in the developing economy with services. For this economy, the evolution of p_{mt} is exogenous and given by the developed world. It is easy to show that steady-state growth rates for all variables remain the same as in the two-sector model, except for the ones that have no mirror in that model; that is, y_{st}^* , p_{st}^* and c_{st}^* . For these ones: $G_{y_s}^* = G_{c_s}^* = G_y^* G_{p_s}^*$, with $G_{p_s}^* = G_{E_a}^{1-\alpha} G_{E_s}^{\lambda-1} G_{E_m}^{\alpha-\lambda} G_L^{\mu-\beta+\gamma(\lambda-\alpha)/(1-\theta)}$.

Let us concentrate now on the diversified production case, whose results the introduction of services could most likely affect. Following the same steps as in section 2, we obtain that income per capita that equals $y_t = l_{at}y_{at} + p_{mt}l_{mt}y_{mt} + p_{st}l_{st}y_{st}$ now reduces to

$$y_t = \frac{w_t}{1-\alpha-\beta} \left[1 + l_{mt} \left(\frac{\theta + \gamma - \alpha - \beta}{1 - \theta - \gamma} \right) + l_{st} \left(\frac{\lambda + \mu - \alpha - \beta}{1 - \lambda - \mu} \right) \right]. \quad (78)$$

This expression delivers the same result as expression (24). In particular, equation (78) says that land raises output if agriculture is less labor intensive than the other two sectors, and *vice versa*.

Comparing across economies, this remains true at steady state because long-run (efficiency-adjusted) FPE holds as well with services. To see this, notice that the Euler equation for consumption (5), and conditions (11), (22) and (41) still hold but with p_t being now relabeled p_{mt} . The system formed by these equalities imply that r_{kt}^{ss}/p_{mt}^{ss} , n_{mt}^{ss} , k_{mt}^{ss} , and w_t^{ss} are the same as their developed-world's counterparts. Hence, under production diversification, a large land endowment decreases l_{mt}^{ss} and l_{st}^{ss} whereas w_t^{ss}/E_t remains equal to w_t^*/E_t^* , thus raising (decreasing) y_t^{ss} if agriculture is the less (most) labor intensive sector.

The impact of having services on our quantitative results is small if the elasticities in the manufacturing and service sectors are similar. To see this, let us go to the extreme and impose $\lambda = \theta$ and $\mu = \gamma$, equations (70) to (72) imply that $k_{st} = k_{mt}$, and $n_{st} = n_{mt}$. Expressions (76) and (77), in turn, say that the relationship between output prices become exogenous; in particular, $p_{mt}/p_{st} = (E_{st}/BE_{mt})^{1-\theta}$. As a consequence, variables and parameters related to the service sector do not show up in the equation system that

governs the model dynamics. The system for a developing economy is now identical to the one of the two-sector model, with the following two exceptions:

$$k_t = k_{mt} \left[l_{at} \frac{\alpha(1-\theta-\gamma)}{\theta(1-\alpha-\beta)} + l_{mt} \right], \quad (79)$$

and

$$n_t = n_{mt} \left[l_{at} \frac{\beta(1-\theta-\gamma)}{\gamma(1-\alpha-\beta)} + l_{mt} \right]. \quad (80)$$

Comparing (79) and (80) to (20) and (21), the difference is that instead of having $1 - l_{mt}$, we now have l_{at} .

Therefore, when input elasticities in the secondary sector are the same as in the tertiary activity, the price of services in the small open economy moves exogenously with the one of manufactures, services no longer play any role in the diversified-production equilibrium, and the model's equation system becomes almost exactly the same as the one in the two-sector model. As a consequence, predictions on the asymptotic convergence speed should as well remain similar.

The evidence says that this assumption is not far from reality. Herrendorf and Valentinyi (2008, table 2) report a share of equipment plus structures of 0.30, 0.28 and 0.36 for manufacturing, services and agriculture, respectively; and a land share of 0.03, 0.06 and 0.18 for the same sectors. Agriculture is clearly more capital intensive and less labor intensive than the rest of the economy.

The conclusion from this section is that the introduction of services into the framework does not change the qualitative results. In addition, taking into account that inputs shares in services and manufacturing are similar, relatively far from the ones in agriculture, and that trade in services is significant, although at about half the scale than in manufacturing and agriculture, the introduction of the tertiary sector should not either have a big impact on our quantitative findings.

C Two-country world: small *versus* open

In this appendix, we explore the relationship between land and long-run income in a two-country diversified production equilibrium. Market clearing conditions (38) and (39) become

$$s^1 c_{at}^1 + (1 - s^1) c_{at}^2 = s^1 l_{at}^1 y_{at}^1 + (1 - s^1) l_{at}^2 y_{at}^2, \quad (81)$$

$$s^1 (c_{mt}^1 + x_t^1) + (1 - s^1) (c_{mt}^2 + x_t^2) = s^1 l_{mt}^1 y_{mt}^1 + (1 - s^1) l_{mt}^2 y_{mt}^2, \quad (82)$$

where the superscript stands for country $h = 1, 2$, and s^1 is the population of country 1 relative to the world population. Proceeding as in the previous case of the world economy in this appendix, we obtain an equilibrium condition that now depends on l_{mt}^A and l_{mt}^B . Note that all the optimality conditions obtained for the small open economy in a diversified production equilibrium apply to countries 1 and 2 in this two-country world. For simplicity, suppose that population growth is zero and that sectorial productivities are constant. The optimality conditions and the Euler equations for each country imply that at the steady state: $n_a^h = n_a^*$, $n_m^h = n_m^*$, $k_m^h/E^h = k_m^* = (\frac{\rho^{-1+\delta}-1}{\theta})^{1/(\theta-1)} n_m^{*\gamma/(1-\theta)}$ and

$l_m^h = \frac{\beta(1-\theta-\gamma)}{\beta(1-\theta-\gamma)-\gamma(1-\alpha-\beta)} \left(1 - \frac{n^h}{n_a^*}\right)$ for all h . Then the market clearing conditions imply that the steady state solution for n_a^* is

$$n_a^* = \frac{s^1 n^1 + (1-s^1) n^2 E^2 / E^1}{s^1 + (1-s^1) E^2 / E^1 + \left(\frac{\gamma(1-\alpha-\beta)}{\beta(1-\theta-\gamma)} - 1\right) \left(\frac{T_2}{T_1+T_2-1}\right)} \quad (83)$$

where n^h is the land-labor endowment of country h , and $T_1 = \frac{\rho^{-1}+\delta-1}{\theta(1+\delta-1)}$ and $T_2 = \left(\frac{1-\theta-\gamma}{1-\alpha-\beta}\right) \left(\frac{\alpha}{\theta} + T_1(1-\varphi)/\varphi\right)$ are positive constants. Use this solution to compute k_m^* and n_m^* and substitute the resulting expressions into (41) to obtain the steady state price of manufactures, $p(n_a^*)$, which is positively related to n^1 and n^2 . In this scenario the long-run per capita values of capital and income in country h are

$$\begin{aligned} k^h &= E^h k_m^* \left[\frac{\alpha(1-\theta-\gamma)}{\theta(1-\alpha-\beta)} + \left(1 - \frac{\alpha(1-\theta-\gamma)}{(1-\alpha-\beta)\theta}\right) l_m^h \right], \\ y^h &= \frac{E^h k_m^*}{\theta} (\rho + \delta - 1) p(n_a^*) \left[\frac{1-\theta-\gamma}{1-\alpha-\beta} + \left(1 - \frac{(1-\theta-\gamma)}{1-\alpha-\beta}\right) l_m^h \right]. \end{aligned}$$

It follows from the first expression and the optimal values of k_m^* and l_m^h that, if agriculture goods are more capital intensive, an increase in the land endowment of country h will have a positive effect on its steady state capital but an ambiguous effect on the capital stock of the other country. And viceversa if manufacture goods are more capital intensive (the ambiguous effect will be on the capital stock of country h and the positive effect will go to the capital stock of the other country). Part of this ambiguity comes from the positive effect of n^h on n_a^* , which depends on the relative size of population in country h . Similarly, it follows from the income expression that the effect of an increase in n^h on y^h is positive if agriculture is more labor intensive than manufactures, otherwise the effect is ambiguous. In this case the ambiguity also comes from the positive effect of n^h on $p(n_a^*)$. Assuming, for example, that both countries have the same population size and the same land-labor endowment, a marginal increase in the land endowment of country 1 always has a positive effect on its long-run income, regardless of capital or labor shares. Moreover, in the limit case when the relative size of country 1 is one (country 1 is large and open, country 2 becomes a small open economy), the total effect of n^1 on l_m^1 is zero, as we showed in (42), and the effect on both long-run capital and income is positive.

D Data Appendix

Table A: 80-country sample

Algeria	Argentina	Australia	Austria	Bangladesh	Belg-Lux [*]	Benin
Bolivia	Botswana	Brazil	Cameroon	C.A.R	Canada	Chile
Colombia	Denmark	Dominican R	Ecuador	Egypt	El Salvador	Finland
France	Gambia	Germany	Ghana	Greece	Guatemala	Haiti
Honduras	Hong Kong	India	Indonesia	Ireland	Israel	Italy
Jamaica	Japan	Jordan	Kenya	Korea Rep.	Lesotho	Malawi
Malaysia	Mali	Mexico	Nepal	Netherlands	New Zealand	Nicaragua
Niger	Norway	Pakistan	Panama	Papua N.G.	Paraguay	Peru
Philippines	Portugal	Rwanda	Senegal	Sierra Leone	South Africa	Spain
Sri Lanka	Sweden	Switzerland	Syrian A.R.	Tanzania	Thailand	Togo
Trin. & Tob.	Tunisia	Turkey	U.K.	Uganda	Uruguay	U.S.A.
Venezuela	Zambia	Zimbabwe				

* When data for the two nations were split, we weighted them using the size of each economy. For some of the instruments and for schooling, the variable only reflects Belgium data; but notice that Belgium represents 95% of the Belg-lux economy.

Table B: Descriptive statistics for core-regression variables

	Mean	Std. Dev.	Std. Dev./Mean	Minimum	Maximum
Y ₁₉₉₆	19130	16930	0.88	907	56426
Y _{growth}	0.40	0.48	1.20	-0.94	1.77
School	5.06	2.74	0.54	0.56	11.12
YearOpen	0.39	0.34	0.87	0.01	1.01
PubDisto	0.10	0.07	0.70	0.01	0.38
AraLand per w.	0.83	0.90	1.08	0.00	6.45
PotALand per w.	4.47	6.68	1.49	0.01	37.72
Area per worker	0.13	0.22	1.69	0.00	1.34
Y ₁₉₆₇	11965	10463	0.87	997	38991

Table C: Variable description and sources

Variable	Description	Source
Endo. and explanatory		
Income	Real GDP, chain, int. 1985 pr., 1967-96	P.W.T. 6.2
Schooling	Aver. years of education, pop ≥ 15 , 1960-95	Barro and Lee (2001)
Openness	% of years open, 1965-90.	Sachs and Warner (1995)
Public consumption	minus education and defense, % GDP, 1970-85	Barro and Lee (1993)
Labor force	'000 of workers, 1967-96	FAOSTAT
Arable land	'000 of hectare of arable land, 1967-96	FAOSTA
Potential arable land	Potential arable land for rainfed agriculture	TERRASTAT
Total land area	Country's land area not under water, '000 km ²	TERRASTAT
Population	'000 of inhabitants, 1967-96	P.W.T. 6.2
Ethnolinguistic Fractionalization	Probability two random people in a country do not speak the same language	Easterly and Levine (1997)
Malaria	Falciparum malaria index, 1966	Gallup et al. (1999)
Life Expectancy	1965	Gallup et al. (1999)
Revolutions and Coups	Number of military coups and revolutions	Barro and Lee (1993)
Rule of Law	Rule of law index	Barro (1996)
Confucian fraction	Fraction of population Confucian	Barro (1996)
Land inequality	Gini coefficient of concentration in 1990	FAO Agricultural Census
Instruments		
Coast	% of land area within 100 km of the coast	Gallup et al. (1999)
Landlock	Dummy variable for landlocked	Gallup et al. (1999)
Water	Country's water area (lakes and ocean)	Gallup et al. (1999)
Absolute latitude	Absolute latitude of the country's centroid	Gallup et al. (1999)
Tropical	% land in geographical tropics	Gallup et al. (1999)
Polar	% land in polar non-desert	Gallup et al. (1999)
Boreal	% land in boreal region	Gallup et al. (1999)
Tropic Desert	% land in Tropical+Subtropical Desert	Gallup et al. (1999)
Other desert	% land in Temperate Desert (+pol+bor)	Gallup et al. (1999)
Dry Temperate	% land in Dry Temperate region	Gallup et al. (1999)
Wet Temperate	% land in Wet Temperate region	Gallup et al. (1999)
Subtropical	% land in Subtropic region	Gallup et al. (1999)
Spanish colony	Dummy for former Spanish colonies	Barro (1996)
French colony	Dummy for former French colonies	Barro (1996)
British colony	Dummy for former British colonies	Barro (1996)
Total land area	Described above	TERRASTAT
Potential arable land	Described above	TERRASTAT
Income per worker	1967, described above	P.W.T. 6.2

References

- Adamopoulos, T., "Land Inequality and the Transition to Modern Growth," *Review of Economic Dynamics* 11(2), 2008.
- Atkeson, A., and P. Kehoe, "Paths of development for early- and late-bloomers in a Dynamic Heckscher-Ohlin Model," *Federal Reserve Bank of Minneapolis working paper*, 2000.
- Ashraf, Q., and O. Galor, "Malthusian Population Dynamics: Theory and Evidence," Brown University, *Mimeo*, March 2008.
- Bajona, C., and T.J. Kehoe, "Trade, Growth and Convergence in a Dynamic Heckscher-Ohlin Model," *NBER Working Papers* 12567, 2006.
- Barro, Robert, "Determinants of Democracy", *Mimeo*, Harvard University, July 1996.
- Barro, Robert J. and Jong-Wha Lee, "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, 32, 3 (December), 363-394, 1993.
- Barro, R.J., and J.W. Lee, "International Data on Educational Attainment: Updates and Implications," *Oxford Economic Papers* 53:541-563, July 2001.
- Barro, R.J. and Sala-i-Martin, X., *Economic Growth*, Macmillan, New York, NY, 1995.
- Bloom, D., D. Canning, and J. Sevilla, "Geography and Poverty Traps," *Journal of Economic Growth* 8:355-378, 2003.
- Caselli, F., and W.J. Coleman, "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation" *Journal of Political Economy* 109(3):584-616, June 2001.
- Caselli, Francesco, Gerardo Esquivel, and Fernando Lefort, "Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics," *Journal of Economic Growth* 1:363-389, September 1996.
- Doppelhofer, D., R. Miller and X. Sala-i-Martin, "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, September 2004.
- Easterly, W., and R. Levine, "Africa's Growth Tragedy: Policies and Ethnic Divisions," *Quarterly Journal of Economics* 112(4), pp. 1203-1250, 1997.
- Echevarria, C., "Nonhomothetic Preferences and Growth," *Journal of International Trade and Economic Development*, 9(2):151-172, June 2000.
- Economic Report of the President*, United States government printing office, Washington, 2004.
- Gallup, J.L., J.D. Sachs and A.D. Mellinger, "Geography and Economic Development," in Pleskovic, B., and J.E. Stiglitz, eds., *World Bank Annual Conference on Development Economics 1998*, Washington: World Bank, 1999.
- Galor, O., O. Moav and D. Vollrath, "Land Inequality and the Emergence of Human Capital Promoting Institutions," *Review of Economic Studies* 75, 2008.
- Galor, O., and A. Mountford, "Trade and the Great Divergence: The Family Connection," *American Economic Review* 96, pp. 229-303, May 2006.
- Galor, O., and A. Mountford, "Trading Population for Productivity: Theory and Evidence", *Review of Economic Studies* 75(4): 1143-1179, October 2008.
- Galor, O., and D. Weil, "From Malthusian Stagnation to Modern Growth," *American Economic Review* 89, 150-154, May 1999.

- Galor, O., and D. Weil, "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and beyond," *American Economic Review* 90(4): 806-828, September 2000.
- Gollin, D., S.L. Parente and R. Rogerson, "The Food Problem and the Evolution of International Income Differences," *Journal of Monetary Economics* 54(4), pp. 1230-1255, 2007.
- Guilló, M.D., and F. Perez-Sebastian, "The Curse and Blessing of Fixed Specific Factors in Small-Open Economies," *Journal of Development Economics*, Vol. 82, 58-78, 2007.
- Guilló, M.D., and F. Perez-Sebastian, "Paths of Development in Open Economies: The Role of Land," *IVIE working paper WP-AD 2005-31*, 2005.
- Guilló, M.D., and F. Perez-Sebastian, "Paths of Development for Early- and Late-Bloomers with Land" *mimeo*, University of Alicante, 2008.
- Gylfason, T., "Natural Resources, Education, and Economic Development," *European Economic Review* 45: 847-859, 2001
- Hansen, G.D., and E.C. Prescott, "Malthus to Solow," *American Economic Review*, 1205-1217, September 2002.
- Hayami, Y., and V. Ruttan, *Agricultural Development: An International Perspective, Revised and Extended Edition*, John Hopkins University Press, 1985.
- Herrendorf, B., and A. Valentinyi, "Measuring Factor Income Shares at the Sectoral Level," *Review of Economics Dynamics* 11, 820-835, 2008.
- Irz, X., and T. Roe, "Seeds of Growth? Agricultural Productivity and the Transitional Dynamics of the Ramsey Model," *European Review of Agricultural Economics* 32(2): 143-165, 2005.
- Jorgenson, D.W., and K.J. Stiroh, "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity* 1, 125-211, 2000.
- Kögel, T., and A. Prskawetz, "Agricultural Productivity Growth and Escape from the Malthusian Trap," *Journal of Economic Growth* 6:337-357, 2001.
- Kongsamut, P., S. Rebelo and D. Xie., "Beyond Balanced Growth," *Review of Economic Studies* 68: 869-882, 2001.
- Lipsey, R.E., "Measuring International Trade in Services," *NBER Working Paper* 12271, May 2006.
- Malthus, T.R., *An Essay on the Principle of Population*. J. Johnson, in St. Paul's Church-Yard, London, UK, 1798.
- Mehlum, H., K. Moene and R. Torvik, "Institutions and the Resource Curse," *Economic Journal* 116: 1-20, January 2006.
- Mountford, A., "Trade, convergence and overtaking," *Journal of International Economics* 46: 167-182, 1998.
- Mundlak, Y., D.F. Larson and R. Butzer, "Rethinking Within and Between Regressions: The Case of Agricultural Production Functions," *Annales d'Economie et de Statistique* 55-56: 475-501, 1999.
- Mundlak, Y., D.F. Larson and R. Butzer, "A Cross-Country Database for Sector Investment and Capital," *The World Bank Economic Review* 14:371-91, 2000.
- Ngai, L.R. and C.A. Pissarides, "Structural Change in a Multi-Sector Model of Growth," *American Economic Review* 97: 429-443, 2007.
- Nichols, D.A., "Land and Economic Growth," *American Economic Review* 60(3): 332-340, June 1970.

- Parente, S.L., and E.C. Prescott, *Barriers to Riches*, MIT Press, 2000.
- Restuccia, D., D.T. Yang and X. Zhu, "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics* 55(2): 234-250, March 2008.
- Sachs, J.D. and A.M. Warner, "The curse of natural resources," *European Economic Review* 45: 827-838, May 2001.
- Sachs, Jeffrey and Andrew Warner, "Economic Reform and the Process of Economic Integration", *Brookings Papers of Economic Activity* #1: 1-95, August 1995.
- Schultz, T.W., "On the Economic Importance of Land: Reply," *Journal of Farm Economics* 49(3): 735-737, August 1967.
- Smith, A., *An Inquiry into the Nature and Causes of the Wealth of Nations*. Ed. by E. Cannan, 1904, Methuen & Co., Ltd, London, UK, 1776.
- Sorensen, P.B., and H.J. Whitta-Jacobsen, *Introducing Advanced Macroeconomics: Growth and Business Cycles*, McGraw-Hill, 2005.
- USDA, *Agricultural Income and Finance Situation and Outlook*, United States Department of Agriculture, Economic Research Service, September 2000.
- USDA, *Agricultural Land Values and Cash Rents: Final Estimates 1999-2003*, United States Department of Agriculture, National Agricultural Statistics Service, Statistical Bulletin No. 993, March 2004.
- USDA, *Major Uses of Land in The United States, 2002*, United States Department of Agriculture, Economic Research Service, Economic Bulletin No. 14, May 2006.
- Ventura, J., "Growth and Interdependence," *Quarterly Journal of Economics*, 57-84, February 1997.

Appendix for referees, not for publication

Table D: Income levels and convergence speeds for alternative parameterizations

<i>Change</i>	α	$N \rightarrow$	<i>Relative steady state income</i>				<i>Convergence speed</i>			
			0.002	0.98	1.98	2.5	0.002	0.98	1.98	2.5
<i>benchmark</i>	0.1		0.218	1.0002	0.989	0.983	n.a.	6.59	7.17	7.53
<i>benchmark</i>	0.3		0.175	0.998	1.077	1.117	n.a.	7.97	7.69	7.57
$G_L = 1.022$	0.1		0.236	1.0003	0.984	0.976	n.a.	7.82	8.43	8.80
$G_L = 1.022$	0.3		0.186	0.997	1.109	1.167	n.a.	8.16	7.87	7.75
$\beta = 0.11$	0.1		0.382	1.002	0.887	1.064	n.a.	5.07	6.12	n.a.
$\beta = 0.11$	0.3		0.370	0.998	1.087	1.062	n.a.	7.19	6.26	5.90
$G_{p^*} = 0.99$	0.1		0.218	1.0002	0.989	0.983	n.a.	9.77	10.46	10.88
$G_{p^*} = 0.99$	0.3		0.175	0.998	1.076	1.117	n.a.	10.17	9.85	9.71
$s_a = 0.3$	0.1		1.008	0.997	0.992	0.987	6.97	7.30	7.69	7.91
$s_a = 0.3$	0.3		0.936	0.998	1.062	1.095	9.78	9.58	9.41	9.33

Table E: GDP-level regression results on 80 country sample

	OLS	GMM	OLS	GMM	OLS	GMM
log(GovConsum)	-0.253*** (0.083)	-0.637*** (0.197)	-0.261*** (0.087)	-0.596*** (0.182)	-0.264*** (0.084)	-0.628*** (0.192)
log(Years Open)	0.097*** (0.038)	0.235** (0.098)	0.097*** (0.038)	0.243*** (0.097)	0.091*** (0.035)	0.233** (0.097)
log(Schooling)	0.856*** (0.132)	0.705*** (0.242)	0.849*** (0.132)	0.711*** (0.242)	0.839*** (0.124)	0.701*** (0.243)
Arable land	0.009 (0.038)	-0.061 (0.061)				
Potential A. L.			0.004 (0.009)	-0.010 (0.013)		
Total land area					0.448* (0.244)	-0.301 (0.266)
R-squared	0.853		0.853		0.860	
Overid. p-value		0.247		0.223		0.253

Dummy variables for Africa, Lantin-America, and East Asia were included in all regressions.

Instruments used are described in data appendix. For definition of variables and data sources,

see also the data appendix. Heteroskedasticity-corrected standard errors are given in parentheses.

*** Significantly different from zero at the 1% level. ** Significantly different from zero at the 5% level.

* Significantly different from zero at the 10% level.

Table F: GDP-growth regression results on 80-Country sample

	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
Gov	*** -0.114 (0.041)	** -0.295 (0.123)	*** -0.101 (0.037)	* -0.182 (0.102)	*** -0.117 (0.041)	** -0.271 (0.114)	*** -0.120 (0.040)	*** -0.337 (0.125)	*** -0.116 (0.040)	*** -0.278 (0.095)	*** -0.137 (0.045)	*** -0.373 (0.125)
Open	0.034 (0.028)	0.076 (0.057)	0.034 (0.028)	0.067 (0.046)	0.032 (0.024)	0.072 (0.053)	0.030 (0.027)	0.098 (0.060)	0.036 (0.028)	0.048 (0.056)	0.023 (0.022)	0.076 (0.063)
School	0.376 (0.106)	0.268 (0.122)	0.376 (0.105)	0.282 (0.112)	0.374 (0.103)	0.215 (0.115)	0.333 (0.115)	0.157 (0.140)	0.377 (0.100)	0.251 (0.117)	0.365 (0.090)	0.297 (0.154)
AL	-0.047 (0.027)	-0.090 (0.040)					0.088 (0.088)	0.163 (0.176)				
PAL			-0.004 (0.008)	-0.014 (0.007)					0.066 (0.055)	0.222 (0.086)		
TA					0.256 (0.363)	-0.434 (0.159)					4.752 (1.502)	8.543 (2.157)
y	*** -0.367 (0.070)	*** -0.380 (0.089)	*** -0.372 (0.078)	*** -0.340 (0.083)	*** -0.393 (0.079)	*** -0.349 (0.086)	*** -0.342 (0.075)	*** -0.369 (0.092)	*** -0.372 (0.073)	*** -0.360 (0.082)	*** -0.368 (0.066)	*** -0.467 (0.089)
AL-y							-0.045 (0.026)	-0.076 (0.054)				
PAL-y									-0.023 (0.016)	-0.074 (0.026)		
TA-y											*** -1.442 (0.441)	*** -2.614 (0.675)
R-squ.	0.595	0.590	0.590	0.130	0.601	0.230	0.603	0.315	0.609	0.773	0.672	0.433
Over. p-v.		0.257										

Dummy variables for Africa, Latin-America, and East Asia were included in all regressions. Gov: log of government consumption to GDP. Open: log of openness index. School: log of average years of schooling. AL: arable land per worker. PAL: potential arable land per worker. TA: total land per worker. y: log of initial income. AL-y: AL in 1966*y.

PAL-y: PAL in 1966*y. TA-y: TA in 1966*y. For definition of variables and data sources, see the data appendix. Instruments used are also described in data appendix.

Heteroskedasticity-corrected standard errors are given in parentheses. *** Significant different from zero at the 1% level. ** Significant different from zero at the 5% level.

* Significant different from zero at the 10% level.

Table G: Robustness checks on level and growth regressions

Regression	Variable	Arable Land		Potential A. L.		Total area	
		OLS	GMM	OLS	GMM	OLS	GMM
Level	Land	0.022 (0.042)	-0.031 (0.065)	0.009 (0.007)	0.001 (0.014)	0.468** (0.228)	-0.197 (0.273)
	RevCoup	-0.650*** (0.212)	-0.929*** (0.256)	-0.689*** (0.229)	-0.933*** (0.259)	-0.650*** (0.222)	-0.910*** (0.260)
Growth	Land	-0.038 (0.027)	-0.077** (0.036)	-0.001 (0.009)	-0.009 (0.007)	0.272 (0.343)	-0.426*** (0.145)
	RevCoup	-0.316** (0.156)	-0.396*** (0.147)	-0.326* (0.178)	-0.320** (0.149)	-0.346** (0.153)	-0.385*** (0.150)
Level	Land	0.024 (0.040)	-0.028 (0.051)	0.003 (0.007)	0.004 (0.010)	0.340 (0.221)	-0.250 (0.214)
	RuleLaw	0.491*** (0.077)	0.578*** (0.118)	0.488*** (0.078)	0.585*** (0.117)	0.475*** (0.076)	0.573*** (0.119)
Growth	Land	-0.028 (0.026)	-0.045 (0.043)	-0.003 (0.008)	-0.008 (0.009)	0.232 (0.317)	-0.340** (0.172)
	RuleLaw	0.263*** (0.083)	0.355*** (0.104)	0.268*** (0.085)	0.348*** (0.108)	0.265*** (0.074)	0.346*** (0.100)
Level	Land	0.034 (0.032)	-0.006 (0.044)	-0.008 (0.007)	-0.000 (0.010)	0.520** (0.226)	-0.025 (0.207)
	Malaria	-0.244 (0.255)	0.195 (0.277)	-0.274 (0.249)	-0.173 (0.276)	-0.261 (0.247)	-0.189 (0.278)
	Lifexp	0.049*** (0.007)	0.063*** (0.017)	0.050*** (0.008)	0.063*** (0.016)	0.051*** (0.007)	0.063*** (0.017)
Growth	Land	-0.027 (0.023)	-0.035 (0.031)	-0.001 (0.006)	-0.010* (0.006)	0.326 (0.339)	-0.258* (0.135)
	Malaria	-0.028 (0.133)	-0.243 (0.163)	-0.027 (0.168)	-0.222 (0.149)	-0.052 (0.135)	-0.208 (0.154)
	Lifexp	0.024*** (0.007)	0.032*** (0.012)	0.024*** (0.009)	0.033*** (0.010)	0.027*** (0.008)	0.028*** (0.011)
Level	Land	0.040 (0.043)	0.121* (0.073)	0.008 (0.008)	0.017 (0.011)	0.538*** (0.209)	0.268 (0.255)
	Ethnolo.	-0.582*** (0.216)	-1.229** (0.256)	-0.595*** (0.215)	-1.060*** (0.239)	-0.624*** (0.208)	-1.119*** (0.262)
Growth	Land	-0.023 (0.027)	0.065 (0.042)	-0.000 (0.009)	0.006 (0.008)	0.334 (0.323)	0.139 (0.187)
	Ethnolo.	-0.414*** (0.136)	-0.837*** (0.154)	-0.430*** (0.148)	-0.749*** (0.158)	-0.480*** (0.147)	-0.773*** (0.183)
Level	Land	0.011 (0.037)	-0.055 (0.063)	0.004 (0.008)	-0.009 (0.013)	0.450* (0.243)	-0.283 (0.269)
	Confu.F.	0.435 (0.513)	0.060 (0.530)	0.431 (0.512)	0.122 (0.526)	0.451 (0.514)	0.078 (0.522)
Growth	Land	-0.045* (0.027)	-0.071* (0.038)	-0.004 (0.008)	-0.011* (0.006)	0.258 (0.362)	-0.365*** (0.145)
	Confu.F.	0.377*** (0.147)	0.341 (0.230)	0.421*** (0.149)	0.448*** (0.179)	0.446*** (0.168)	0.407** (0.203)
Level	Land	-0.042 (0.058)	-0.077 (0.061)	0.018 (0.017)	-0.018 (0.024)	-0.194 (0.216)	-0.260 (0.257)
	Land ineq.	0.547 (0.386)	-1.924 (1.360)	0.494 (0.343)	-1.935 (1.382)	0.542 (0.386)	-1.767 (1.347)
Growth	Land	-0.043 (0.049)	-0.138*** (0.052)	-0.015 (0.015)	-0.047* (0.025)	-0.256 (0.177)	-0.597** (0.240)
	Land ineq.	0.250 (0.258)	-0.490 (0.567)	0.206 (0.214)	-0.833 (0.593)	0.247 (0.261)	-0.198 (0.675)
Level	Density					0.000*** (0.000)	0.000 (0.000)
Growth	Density					0.000*** (0.000)	0.000 (0.000)

Additional groups of variables were introduced in the regression one at a time. Instruments, variables and sources are described in the appendix. Heteroskedasticity-corrected errors in parentheses. *** Significantly different from 0 at the 1% level. ** Significantly different from 0 at the 5% level. * Significantly different from 0 at the 10% level. When density was introduced in the regressions, land per worker was excluded.